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11. ARGUMENTATION IN SCIENCE EDUCATION RESEARCH: PERSPECTIVES FROM EUROPE

INTRODUCTION

Argumentation studies in science education are relatively young. It can be said that classroom-based research in scientific argumentation began in the 1990s. The first batch of studies focused on exploring whether science classroom environments favoured argumentation, an exploration with negative outcomes (e.g., Driver, Newton & Osborne, 2000), as well as on investigating students' argumentation (e.g., Duschl, Ellenbogen, & Erduran, 1999; Jiménez-Aleixandre, Bugallo & Duschl, 2000; Kolstø, 2006; Kortland, 1996). As the field continued to develop, the focus shifted towards an interest in the quality of arguments, or how to analyze the development of students' argumentation competences (e.g., Erduran, 2008; Erduran, Simon & Osborne, 2004). In the last few years there is an emerging interest about how to support students' engagement in argumentation, through the design of learning environments (e.g., Jiménez-Aleixandre, 2008; Mork, 2005) and professional development of science teachers (e.g, Erduran, Ardac & Yakmaci-Guzel, 2006; Erduran, 2006; Simon, Erduran & Osborne, 2006).

In this chapter, we present an overview of how argumentation studies in science education have developed over the past two decades, with a particular focus on the work of European scholars. An extended discussion of the argumentation literature throughout the world is available in the edited volume by Erduran and Jimenez-Aleixandre (2008). We situate the policy context in Europe that has created the precedence for the inclusion of argumentation in the science curriculum. Here we elaborate on the notion of 'competences' that has been developed as part of the European Union (EU, 2006) and the Program for Indicators of Student Assessment (PISA) framework (OECD, 2006). We then turn our attention to the role of language sciences in the development of perspectives about argumentation and linguistics, particularly in France. Next we highlight the models of 'argument' that European researchers have used in their work as well as the framework of 'socio-scientific issues' that have underlined an extensive body of literature related to argumentation. We trace some of the developments in the strategies that support students' argumentation including the use of Information and Communication Technologies (ICT), as well as the approaches to the professional development of science teachers. The chapter ends with an outline of some future perspectives for a European agenda for research, curriculum design and teacher education in argumentation.

Doris Jorde and Justin Dillon (Eds.), Science Education Research and Practice in Europe: Retrospective and Prospective, 253–289.

ARGUMENTATION IN THE FRAME OF DEVELOPMENT OF COMPETENCES

Argumentation studies about science education contexts in Europe share most theoretical frames and methodological approaches with argumentation research worldwide, including a definition of argumentation as the evaluation of knowledge claims in the light of available evidence. Researchers from different continents interact in joint symposia in conferences, co-author papers and contribute to books. As an instance, from the 22 authors in a book we recently co-edited (Erduran & Jiménez-Aleixandre, 2008), half are based in European countries, half in the United States. However, there are four particular features of the European studies worth examining. First, European scholars have been situated within the policy context of 'competences' advanced by the European Union policies. Furthermore, the rationales of some European researchers draw on the field of language sciences to a greater extent than in other regions in the world. Third, a considerable proportion of work conducted in Europe belong to a strand focusing on socio-scientific issues (SSI), which may shed light on similar areas of research in other parts of the world. Finally, there may be particular ways in which European science education researchers' work has had an impact on policy and practice of argumentation. In this section we examine these features and how they shape the research in argumentation across European institutions.

A distinctive feature of argumentation studies in Europe, and in general of the attention given to argumentation throughout Europe in the last decade, is its connection to the development of competences (Jiménez-Aleixandre et al., 2009). In particular, argumentation is framed in the development of scientific competence. Jiménez-Aleixandre et al. support this claim on the characterization of scientific competence, both in the European Union recommendation of eight key competences (EU, 2006), and in the Program for Indicators of Student Assessment (PISA) framework (OECD, 2006). This connection to competences may distinguish argumentation studies carried out in Europe from those undertaken in the United States, for example, where argumentation is framed in scientific practices (e.g. Berland & Reiser, 2009). However, both approaches are convergent, as European argumentation studies set as an explicit goal for students the engagement in scientific practices (e.g., Puig & Jiménez-Aleixandre, 2011).

The PISA framework addressed the notion of scientific competence since 1999, several years before than the EU recommendation. PISA emphasizes three dimensions of the scientific competence (OECD, 2006, p. 29) characterized as the abilities to:

– Identify scientific issues and questions that could lend themselves to answers based on scientific evidence;
– Explain or predict phenomena by applying appropriate knowledge of science;
– Use scientific evidence to draw and communicate conclusions, and to identify the assumptions, evidence and reasoning behind conclusions.

From these points, it is the third one that can be identified as targeting the same practices as argumentation, namely the use of evidence to evaluate scientific claims, be it to draw conclusions from evidence or to identify the evidence behind conclusions. Although, certainly, the three dimensions are connected and support one another.

We can examine now how scientific competence is defined in the European reference framework. “Competence in science refers to the ability and willingness to use the body of knowledge and methodology employed to explain the natural world, in order to identify questions and *to draw evidence-based conclusions*.” (EU, 2006, page L 394/15, our emphasis). This definition collapses the three dimensions of the PISA notion of scientific competence, including the use of evidence and, implicitly, argumentation.

In the half-decade since this reference framework was issued, its recommendations have been translated into the steering documents of many European countries. We will discuss argumentation in policy documents at the end of this section. However, it is worth noting that, in a recent report about 15 European countries participating in the EU-funded S-TEAM project, Jiménez-Aleixandre, Puig and Gallástegui (2010) found that, in nine of them, argumentation was used with the meaning of evaluation of claims, hypothesis and conclusions. That meaning is cohesive with the characterization of scientific competence in the EU framework. Framing argumentation in scientific competences as well as in general competences means that the emphasis is on the ability to apply knowledge and skills in diverse contexts and settings. In other words, learning to participate in argumentation, learning to use evidence to support claims, to back up explanations, in summary, is to participate in scientific practices.

ARGUMENTATION AND THE LANGUAGE SCIENCES

There are at least four theoretical bodies framing argumentation studies: developmental psychology, including the distributed cognition perspective; philosophy, as for instance the theory of communicative action; language sciences; and science studies, that is history, philosophy and sociology of science. As we have discussed elsewhere (Jiménez-Aleixandre & Erduran, 2008), rather than being a one-way relationship, argumentation studies and science education have the potential to inform these perspectives, leading to fruitful interactions. However, one thing is the existence of these potential interactions and another the relationships among different fields, which are currently nonexistent in most cases. As Buty and Plantin (2008a) point out, in their introduction to a volume reporting work on argumentation from seven French science education research groups, the established community in argumentation studies does not take into account the substantial work on argumentation in science education in the last two decades. Evidence for this lack of attention can be found in reference books, in the scarce presence of science education related papers in journals as *Argumentation* and in the proceedings of the ISSA (International Society for the Study of Argumentation) conferences, or in the conspicuous absence of a strand about argumentation in science education contexts in the list of the 18 themes for the ISSA 2010 conference.

An example of cooperation among different fields, constituting an exception to this compartmentalisation, is found in the French research groups, where science educators work alongside with philosophers, psychologists or researchers from language sciences. We will focus our discussion on this case. In the book edited by Buty and Plantin (2008b), four chapters are co-authored by scholars from outside science education, and one of the book editors, Christian Plantin, belongs to the field of language sciences and even to the argumentation studies community. This collaboration is related to a robust tradition of argumentation studies by French language scientists, providing theoretical frames from which science educators draw in their work. Two influential authors are Oswald Ducrot (1972–1998), focusing on the role of language in argumentation, and on semantics and polyphonic utterances, and the Swiss Piagetian scholar Jean-Blaise Grize (1996), whose work is more concerned with natural logic, and the cognitive processes in argumentation. Grize proposed some notions for argumentation analysis that include schematization and a dialogic production assuming an audience, both of which have been extensively used by French science educators in argumentation studies. Unfortunately, none of Grize's books and only one of Ducrot's (Ducrot & Todorov, 1987) are translated into English, and only a few of the French researchers on argumentation in science education, besides Plantin, publish in English, such as Simonneaux, (2008) and Albe (2008), whose work is discussed in the section about SSI.

The interactions between linguistics and science education are not unproblematic. Buty and Plantin (2008a) caution against the temptation to consider all linguistic interactions as argumentative, proposing a restricted characterisation of argumentation as the process of contrasting two views or two incompatible meanings and of negotiating a solution. It follows that not all tasks or activities involving discursive interactions can be regarded as argumentative, but only those involving, for instance, formulating claims, supporting them (we would add supporting them with evidence), or evaluating arguments. On the other hand, argumentation in science education is not just a linguistic activity, but requires drawing from the relevant knowledge, selecting appropriate documentation and information sources, analyzing it by means of particular skills.

An interesting point raised by Plantin (2005) is the relationship between argumentation and rhetoric, criticizing a biased view of rhetoric, which identifies it with manipulative moves. But, as he points out, persuasion (and therefore, rhetoric) is a part of the argumentation process. The relevance of persuasion as one of the goals of argumentative practice is also highlighted by Berland and Reiser (2009), who found that students did not subscribe to it. Plantin (2004) has argued for giving consideration to the place of emotions in argumentation, acknowledging that they may be positive or negative, a point that has relevance for the analysis of argumentation in SSI. In summary, argumentation studies in science education contexts by French researchers offer an example of productive interactions with language sciences. We are not implying that these interactions do not occur outside of France or indeed Europe, as they are exemplified for instance in the work of Kelly and colleagues (Kelly & Bazerman, 2003), but that the development of this work in France has occurred independently and this cooperation is a useful example of how to extend work in science education contexts to other fields.

MODELS OF ARGUMENT

The work of science educators in Europe has drawn on a range of perspectives on argument and argumentation (e.g. van Eemeren et al., 1996; Perelman & Olbrechts-Tyteca, 1958; Toulmin, 1958; Walton, 1996), as well as linguistic perspectives on discourse and communication (e.g., Bronckart, 1996; Grize, 1996), particularly from French researchers, as discussed above. The research emphasis in science education has typically concentrated on a definition of argument based on the work by Stephen Toulmin (e.g. Erduran & Villamanan, 2009; Erduran, 2007; Erduran, Simon, & Osborne, 2004; Jiménez-Aleixandre, Bugallo, & Duschl, 2000; Jiménez-Aleixandre & Pereiro, 2002; von Aufschnaiter, Osborne, Erduran & Simon, 2008) whilst the use of Douglas Walton's model has been relatively minimal in science education across the world at large (e.g. Duschl, 2008) and in Europe in particular (e.g. Jiménez-Aleixandre, Agraso & Eirexas, 2004; Ozdem, Ertepinar, Cakiroglu, & Erduran, in press). Although these two models (Figure 1 and Table 1) have often been presented as a contrast to each other, it is worthwhile to highlight that they actually address different aspects of argument and argumentation (Erduran, 2008). Toulmin's framework concentrates on the components of an argument whereas Walton's schemes detail different types of arguments.

Toulmin's model of argument has been used as a methodological tool in the characterisation of teaching and learning processes in the science classroom (e.g. Erduran et al., 2004; Jiménez-Aleixandre et al., 2000) as well as a pedagogical and learning tool (Osborne, Erduran & Simon, 2004). For example, in the IDEAS Project, writing frames for supporting learners have been generated with statements such as "My idea is…", "My reasons for my idea are…", "I believe in my reasoning because…" which were derived from the features of Toulmin's model in terms of claims, data, warrants and so on (Osborne, Erduran & Simon, 2004). In the Mind the Gap Project, Toulmin's frame has been used to support teachers in introducing argumentation in the classroom (Jiménez-Aleixandre et al., 2009). Also in this project, to be detailed later in this chapter, we have developed our understanding of how science teachers engage in the use of such writing frames (Erduran & Yan, 2009; Erduran & Yan, 2010).

Claims: **Assertions about what exists or values that people hold.**
Data: **Statements that are used as evidence to support the claim.**
Warrants: **Statements that explain the relationship of the data to the claim.**
Qualifiers: **Special conditions under which the claim holds true.**
Backings: **Underlying assumptions that are often not made explicit.**
Rebuttals: **Statements that contradict either the data, warrant, backing or qualifier of an argument.**

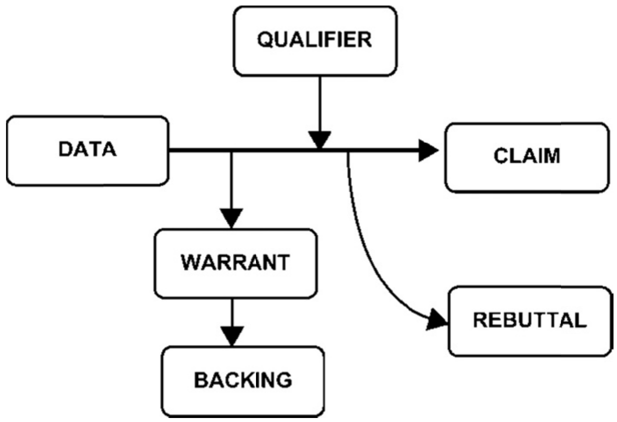

Figure 1. Toulmin's argument model (from Toulmin, 1958).

Table 1. Selected schemes from Walton's Presumptive Reasoning (Duschl, 2008)

Argument Form:	*Definition*
Sign	Reference to spoken or written claims are used to infer the existence of a property or occurrence of an event.
Commitment	A claims that B is, or should be committed to some particular position on an issue, and then claims that B should also be committed to an action.
Position to Know	A has reason to presume B has knowledge of or access to information that A does not have, thus when B gives an opinion, A treats it as true/false.
Expert Opinion	Reference to an expert source external to the given information.
Evidence to Hypothesis	Reference to premises followed by a conclusion.
Correlation to Cause	Infers a causal connection between two events from a premise describing a positive correlation between them.
Cause to Effect	Reference to premises that are causally linked to a non-controversial effect.
Consequences	Practical reasoning in which a policy or course of action is supported/rejected because the consequences will be good/bad.
Analogy	Used to argue from one case that is said to be similar to another.

Some examples of uptake of Walton's model in science education research have been used among doctoral candidates and researchers across Europe. For instance, in Spain, Cristina Pereiro and Marta F, Agraso at the University of Santiago de Compostela, and Aikaterina Konstantinidou at University of Barcelona; Stein Dankert Kolstø in Norway and Yasemin Ozdem at Middle East Technical University in Turkey have incorporated the Walton framework as part of their methodological approaches in their research. Some of the preliminary research from Ozdem's dissertation is a particular illustration of how Walton's framework can be used to differentiate affordances for types of tasks and arguments generated as a result of engagement in these tasks. Results of her study (ie. Ozdem et al., in press) illustrated that some kinds of argumentation schemes were more frequently used in all tasks, whereas others were specific for tasks. For example, *argument from sign, argument from example, argument from evidence to hypothesis, argument from correlation to cause, argument from cause to effect,* and *argument from consequences* were generated in all tasks. Therefore, these argumentation schemes can be interpreted as task-independent. It is quite possible that these argumentation schemes would appear in scientific contexts where participants have some background knowledge on the issue. On the other hand, there were other argumentation schemes that appeared specifically on one or more tasks, but could not be located in others. For example, *argument from verbal classification* and *argument from expert opinion* could only be located in certain tasks and not others.

In Cristina Pereiro's doctoral dissertation about students' argumentation in the context of environmental management, Walton's categories about argument from expert opinion have been used to examine the issues of scientific authority and expertise in students' discourse (Jiménez-Aleixandre & Pereiro-Muñoz, 2002). For instance, students' positions about their own status as experts evolved during the 17 sessions of the teaching sequence, from expressing doubts about their capacity to critizice the engineers' technical proposal, to confidence in their own competence. Students also made appeals to consistency with evidence, one of Walton's categories of arguments from expert opinion.

In her research, Agraso (e.g., Jiménez-Aleixandre, Agraso & Eirexas, 2004), draws on Walton's distinction among explicit and implicit commitments of participants in a dialogue. Walton distinguishes two sides in the commitment-set of each participant: *light side*, propositions known or in view to all the participants, and *dark side*, propositions not known or visible. Jiménez-Aleixandre et al. use this distinction in their analysis of students' argument about an oil spill. This study also explored students' evaluation of the expertise of the scientists whose positions were discussed.

Kolstø (e.g., Kolstø & Ratcliffe, 2008) has also made use of these two Walton schemes, arguments from expert opinion and the potential bias or dark side in experts' claims. Bronckart's (1996) frame about argumentation markers or modalizations has been used by Simonneaux (2008) as a tool to teach argumentation to a group of 12th grade participants. These argumentation markers represent different degrees and types of agreement with the content of a given piece of discourse and, according to Bronckart can be: logical (certainty or probability), deontic (social values), appreciative (subjective) and pragmatic (personal responsibility). Simonneaux found that the frame helped students of the intervention group to develop more sophisticated written arguments than the control group. Simonneaux (2001) has also made use of Grize's (1996) frame for comparing the effects of role-play and debate teaching strategies on the quality of argumentation.

A relatively recent interest in the work of some doctoral researchers has been the extension of the argument models in science education to be more inclusive of activity systems in which argumentation takes place. For example, the ongoing dissertation work of Xiaomei Yan and Demetris Lazarou (Lazarou, in press) both working with Erduran at University of Bristol, has been using Engeström's notion of 'activity theory' (Engeström, 2005). Yan has been focusing on chemistry undergraduate students' learning of argumentation in the broader context of their lectures, laboratory instruction as well as independent research in a community of researchers. Lazarou himself was a primary school teacher in Cyprus and has been working with primary school teachers to study the ways in which a group of primary school teachers engage with argumentation across various contexts including workshops and classroom teaching with an emphasis on framing the activities in a longitudinal fashion using the key concepts of activity theory, such as division of labour, objects and subjects.

A further aspect of the notion of 'argument' in the work of science educators in Europe has been the emphasis on socio-scientific issues. As one of the early contributors to argumentation research in Europe, Rosalind Driver had paved the way for the socio-scientific framing of argumentation by highlighting the significance of children's images of science and adequate representation of the socially constructed nature of science (Driver, Newton, & Osborne, 2000). A line of research focusing on argumentation in the context of socio-scientific issues has emerged across Europe in the work of researchers in Norway (e.g. Kolsto, 2001; Mork, 2005), France (e.g. Simmonneaux, 2001; Albe, 2005), England (e.g. Grace & Ratcliffe, 2002), Greece (e.g. Patronis, Potari, & Spiliotopoulou, 1999), Israel (e.g. Zohar & Nemet, 2002) and Spain (e.g. Jiménez-Aleixandre & Pereiro-Muñoz, 2002). Among other things, the work on argumentation in the context of socio-scientific issues has highlighted the need to characterize science from an interdisciplinary perspective (Simonneaux, 2008).

ARGUMENTATION IN THE CONTEXT OF SOCIO-SCIENTIFIC ISSUES

Argumentation studies focusing on socio-scientific issues (SSI) are carried out in many regions of the world, as reviewed for instance by Simonneaux (2008) and Sadler (2009). In Europe, this strand of studies has been particularly fruitful, constituting a substantial proportion of the work on argumentation. Socio-scientific issues are characterized as social dilemmas or controversies rooted in scientific domains (Simonneaux, 2008), or as issues and problems with two elements: a) conceptual and/or procedural connections to science and b) social significance (Sadler, 2009). According to Kolstø and Ratcliffe (2008), science is involved in a social debate over these issues, typically concerning personal or political decision-making related to health or environmental controversies. The notion of SSI is grounded on previous approaches such as as Science – Technology – Society or

Science-based social issues. In the French-speaking community, SSI overlaps with a field called "questions socialement vives" (QSV), translated by Simonneaux (2008) into "socially acute questions". QSV have a broader scope than SSI, comprising both issues from science education and from history and social sciences education, such as issues about immigration, European identity or unemployment. All these issues are widely discussed in society and in the classrooms, as illustrated in the volume edited by Legardez and Simonneaux (2006) about QSV-based teaching, a work emphasizing the interactions among science education and other fields in the French community as discussed earlier. They can be viewed in the perspective of citizenship education and, in the case of science education, as a contribution towards the goal of science for citizenship.

It needs to be noted that the social relevance of SSI cannot obscure the science dimension embodied in them. Typically, reaching decisions on SSI issues requires students to master scientific models, concepts and skills, as well as knowledge about science. The science dimension of SSI is examined by Kolstø (2001a) who proposes an analysis framework composed of eight content-transcendent topics. Kolstø defines content-transcendent knowledge as knowledge *about* science rather than knowledge *in* science. The content-transcendent topics are grouped under four headings: a) science as a social process; b) limitations of science; c) values in science; and d) critical attitude. He sees this notion as related to the widely used term "nature of science", but broader. The goal of this framework is to address three problems faced by science educators when teaching controversial SSI in secondary school, first, which specific content-transcendent topics should be taught, second, the relevance of the knowledge for the students' lives, and third, the need to adjust the amount of content-transcendent knowledge to be within the intellectual reach of most students. Kolstø argues that each of these eight topics can serve as a tool for students when examining the science dimensions of SSI. The framework holds potential for SSI-based teaching and some of its topics including the demands for underpinning evidence, the criteria about what counts as evidence and a critical attitude related to the scrutiny of scientific evidence, are highly relevant for learning argumentation.

While all socio-scientific issues are scientific, it needs also to be acknowledged that the controversies, either in the classroom or in society, have sometimes a strong ethical component, while in other cases students need to appeal primarily to scientific explanations (Jiménez-Aleixandre, 2010). In other words, values and ethics might at times pose dilemmas in scientific argumentation. To take some instances grounded in genetics, decisions about cloning (Jiménez-Aleixandre & Federico-Agraso, 2009) or genetic screening (Zohar & Nemet, 2002) require students to know about genes and inheritance, but a great weight in their options would relate to values. On the other hand, to argue about the relative weight of genes and environment on human performances as athletics, or on intellectual achievements (Puig & Jiménez-Aleixandre, 2011), demands from students to apply causal explanations about gene expression, although social representations may influence their claims. Another example of a strong science component is the work about marine resources management by Bravo-Torija & Jiménez-Aleixandre (2012). Students need to understand and apply the complex model of energy flow in ecosystems, in order to reach a decision about whether to eat carnivorous or herbivorous fish, two options with different impact on sustainability.

Kortland (1996; 2001) published one of the first European studies exploring argumentation about SSI, in the frame of developmental studies undertaken at the University of Utrecht. He examined the effect of consecutive versions of a teaching sequence in secondary school (students aged 13–14) about decision-making on waste management. The tasks required students to criticise different arguments about the choice of a milk container and then to derive the requirements of a well-argued position. This task proved to be extremely difficult, and the effect of the intervention on the quality of the student's argumentation was limited. This limited effect was attributed by Kortland (1996) to the lack of attention paid to supporting students' reflection on their own arguments.

Another early work about SSI and decision-making was Ratcliffe's (1997), with secondary school students, all male (14–15 year old) in the UK. Students were asked to decide what materials –aluminium, PVC, softwood, hardwood– would they use for window frames. They discussed the advantages and disadvantages of each option, but in some cases they were persuaded by one of the members of the group. Ratcliffe discussed the effect of using values shared among the students (sometimes egocentric), rather than scientific evidence, to back their options. She pointed out the interrelationship between affective and cognitive criteria in reaching a decision. This research program was continued in the work of Grace (2009) about the quality of 15–16-year-old students' reasoning on the conservation of biodiversity. The study examined the effect of using a structured framework for decision-making debates on the improvement of the quality of students' arguments. Grace found an increase in the arguments' quality, and suggested the relevance of students' reflection on their own ideas.

Patronis, Potari and Spiliotopoulou (1999) examined the arguments of 14-year-old students, while choosing among several courses of action about the plans for a road, a teaching sequence based on an actual controversy in their local setting in Greece. The students progressed from individual work, to group reports and finally had to agree on a class decision. The authors attributed the coherence of the students' arguments to the relevance of the problem, close to their daily lives, and to the personal commitment of students in the search for solutions.

In France, focusing on work published in English, Laurence Simonneaux has conducted a research program on SSI, about issues as biotechnology (Simonneaux, 2001). She compared the impact of two teaching strategies, role-play and debate, on students' argumentation. The study showed that arguments were more complex in the debate, while in the role-play students used more rhetorical schemes. Other dimensions of her studies are reviewed in Simonneaux (2008). Virginie Albe began her work in Simonneaux's research group. She has focused on teaching controversies (Albe, 2009), analyzing argumentation about the potential health risks of cell-phones with 11th grade students, (Albe, 2008a) and about climate change (Albe, 2008b). In the study about cell-phones she identified processes of group argumentation, as well as the influence of students' epistemological representations and of social interactions in the argumentation patterns.

The work of Stein Dankert Kolstø, in the University of Bergen, Norway, combines theoretical reflections and empirical studies, in a perspective of science education for citizenship (Kolstø, 2001a). An instance of his theoretical work is the framework, discussed at the beginning of this section (Kolstø, 2001a), about the complex interplay between science and social context. His empirical research focuses on students' ways of examining and evaluating the science dimension of controversies and in how they use science in their own argumentation. An instance of the examination about students' judgements of information in a socio-scientific issue is his study about 16 year old students' views on the risk of power transmission lines (Kolstø, 2001b). For instance, he found how some of them accepted information from scientists without evaluating its reliability. Patterns in students' arguments and their use of science in them are explored in a paper about the same SSI of risk of power transmission lines (Kolstø, 2006). Overall, Kolstø's work has as a goal to support students in reflective decision-making and in performing evidence-based argumentation.

At the University of Oslo, also in Norway, Sonja Mork's doctoral dissertation focused on the teacher's (and researcher's) role in the management of argumentative role-play debates (Mork, 2005a), as well as on the contribution of ICT to the introduction of argumentation and SSI in science classrooms (Jorde & Mork, 2007). (This second issue discussed below in the section about ICT and argumentation.) The problem of wolves was used to involve students in dealing with contradictory evidence and in providing justifications for their claims. Mork identified several types of teacher's interventions, for instance: to model how to behave in a debate, to challenge the accuracy of the information provided by the students, to extend the range of topics introduced by the students, to get the debate back on track, to rephrase students' statements, and to promote participation. It needs to be noted that learning about ecology was one of the goals of the teaching sequence, alongside with practising argumentation.

A recent doctoral dissertation that, as Mork's, combines the SSI context with a focus on the contribution of ICT towards supporting argumentation is Maria Evagorou's work (Evagorou, 2009). Her study explores the argumentation processes of 12–13 year old students in the UK. They were asked to engage in arguments about a UK government's mass culling programme for the grey squirrel, which involved poisoning or shooting part of them. Red squirrels are native to the UK, while the grey squirrel was introduced in the 19th century. The population of the red has been declining while the grey is now found in more regions of the country. Scaffolding was provided for students' construction of argument by means of the Argue-WISE online learning environment (Evagorou and Osborne, 2007). The nature of students' decisions and how they changed during instruction is addressed in Evagorou, Jiménez-Aleixandre and Osborne (2012).

The work about SSI in project RODA in Spain is discussed in the next section in the context of the argumentation research programme lead by Jiménez-Aleixandre at the University of Santiago de Compostela. Introducing SSI in science classrooms is challenging, as these are complex issues and working with them puts high demands on teachers. Researching them is equally demanding. However, as Kolstø (2001a) points out, these are the kind of issues students are likely to be confronted with in their lives.

SUPPORTING STUDENTS' ARGUMENTATION IN SCIENCE

Numerous science educators across Europe have been involved in the development of resources to support the teaching and learning of argumentation, as evidenced in the previous account about argumentation in SSI contexts. In this section, we will discuss our own work conducted in England (Erduran) and in Spain (Jiménez-Aleixandre).

In England, Osborne, Erduran and Simon have developed a video-based training resource (in the IDEAS Project) that promotes a set of frameworks intended to support the learning of argument (Osborne, Erduran, & Simon, 2004a,b). The Nuffield Foundation supported the development of the IDEAS Project, included a teacher training resource DVD as well as lesson materials for teachers. The argumentation frameworks are generic in nature and can be adapted to different subjects and topics. Erduran has applied the "Constructing an argument" framework in chemistry in the context of laws (Erduran, 2007). In this framework, the students can be presented with an observation about the Periodic Law and they are given a number of statements that would either support or refute this observation. They can then be asked to select the piece of evidence from the statements that best supports the observation. For example, the group of calcogens are neither metals nor non-metals. The group of calcogens (oxygen, sulphur, Selenium, Tellurium, Polonium, Ununhexium) share a spectrum of properties of metals, semi-metals and metals. The physical properties of Selenium (grey metallic) do not match its non-metal chemical properties. Tellurium is silvery grey and semi-metallic. The extent to which students can use the rest of the Periodic Table and knowledge of the Periodic Law to support which calcogens are more likely to be metallic and which non-metallic can create a forum for the selection, evaluation and justification of evidence. The IDEAS Project resources have been adapted and used with pre-service science teachers in Turkey (Erduran, Ardac, & Yakmaci-Guzel, 2006).

A network of projects was also carried out in England with the financial support of the Gatsby Foundation. The project aimed to produce resources for student-teachers and pupils so as to facilitate the teaching and learning of ideas and evidence in science at Key Stage 3 (Braund, Erduran, Simon, Taber, & Tweats, 2004). This 'Ideas and Evidence' project was carried out at several British universities: Cambridge, Keele, Institute of Education, King's College London and York. For example, the King's College materials consisted of five sets: one focusing on assessment for learning, one focusing on supporting writing and three focusing on teaching ideas and evidence in particular science contexts such as explaining combustion and the rotation of the Earth (Erduran, 2006). In producing the resources, a particular emphasis was placed on the role of evidence in scientific ideas – that is, how we know what we know in science and how we justify scientific knowledge. There were two meetings when the mentors and the tutors had the opportunity to discuss and refine the materials. The purpose of the first meeting was to introduce the mentors to some resources and generate a plan of action for the project. The mentors then went back to their schools and worked with trainee teachers who implemented the lessons. Nine mentors and eleven trainee teachers were recruited for the King's project. Five university-based tutors produced the materials and conducted the workshops. At the second meeting, the mentors and trainees shared their experiences and provided feedback on the effectiveness of the materials. The university-based tutors subsequently revised some of the materials in light of the suggestions from the mentors towards publication.

The activities produced as part of the King's project included many science topics including chemistry. The 10 sets of materials are consistent with the curricular goals set by the Key Stage Three Strategy. The materials are organised as activities that included some guidelines for teachers and materials for pupils. The activities are titled as follows: (1) Acids & Alkalis; (2) Changes in Matter; (3) Sliding on Surfaces; (4) Cells; (5) Constructing a Written Argument; (6) Chemical Reactions and Measurement; (7) Compounds & Mixtures; (8) Environment & Health; (9) Examining a Scientific Argument; and (10) Ideas & Evidence & Use of Formative Assessment. The example activity sheet for the "Changes in Matter" lesson is shown in Figure 2.

Changes in Matter!

Theory 1: **Burning a piece of paper is like boiling water. Both paper and water change in their compositions in the same way.**

Theory 2: **Burning a piece of paper is very different from boiling water. Paper changes its composition, but water does not.**

Evidence Statements:

Heat is needed to burn paper and boil water.	Gas is released when water boils and paper burns.
When paper burns ash is left, but when pure water boils away nothing is left behind.	A chemical reaction occurs when reactants change into new products.
As a liquid is heated, its molecules gain energy and move more and more quickly.	Eventually, the bonds between molecules are no longer strong enough to keep the molecules close together.
It is possible to get the liquid water back by condensing the water vapour, but it is not possible to get the paper back after it has been burned.	Burning happens when an element or a compound reacts very vigorously with oxygen.
When matter undergoes phase transitions, it changes its state from solid to liquid to gas.	When matter undergoes phase transitions, it changes its state from solid to liquid to gas.

Figure 2. Student activity sheet on "Changes in Matter" using the competing theories framework to promote ideas, evidence and argument (from Erduran, 2006).

More recently, the production of teaching and learning sequences in argumentation has been a key objective of the Mind the Gap and S-TEAM projects described in more detail in the professional development section of this chapter. Teams of researchers in Santiago de Compostela, Spain and Bristol, England have been collaborating with secondary science teachers to generate resources, some of which have already been published (e.g. Erduran & Yan, 2009; Jimenez-Aleixandre, 2009).

Table 2. Frameworks for Supporting Argumentation in the Science Classroom
(from Osborne, Erduran & Simon, 2004a)

Framework	*Description*
1. Table of Statements	Students are given a table of statements on a particular science topic. They are asked to say if they agree or disagree with the statement and argue for their choices. This idea has been developed from the work on discussing instances of physical phenomena (Gilbert & Watts, 1983)
2. Concept Map of Student Ideas	Students are given a concept map of statements derived from student conceptions of a science topic derived from the research literature. They are then asked to discuss the concepts and links individually and as a group to decide whether they are scientifically correct or false, providing reasons and arguments for their choice. This was an adaptation of the common use of concept mapping (Osborne, 1997)
3. A Report of a Science Experiment Undertaken by Students	Students are given a record of another student's experiment and their conclusions. The experiment is written in a way to intentionally include information that is lacking or in a manner could be improved, so as to stimulate disagreement. Students are asked to provide answers to what they think the experiment and its conclusions could be improved, and why. This idea was drawn from the work of Goldsworthy, Watson and Wood-Robinson (2000)
4. Competing Theories – Cartoons	Students are presented with two or more competing theories in the form of a cartoon. They are asked to state which they believe in and argue why they think they are correct. The work of Keogh and Naylor (Keogh & Naylor, 1999) has been valuable in developing a resource which is an excellent stimulus to engaging children with scientific thinking.
5. Competing Theories – Story	Students are presented competing theories in the form of an engaging story reported in a newspaper. They are then asked to provide evidence for which theory they believe in and why.
6. Competing Theories – Ideas and Evidence	In this approach, students are introduced to a physical phenomenon and then offered two or more, but generally two, competing explanations. In addition, a

	range of statements of evidence that may support one theory, the other, both or neither are provided. In small groups, students are then asked to consider each piece of evidence and evaluate its role and significance. Finally, they must use the evidence to argue for one idea or another. This idea has been adapted from the work of Solomon and colleagues (Solomon, Duveen & Scott, 1992).
7 Constructing an Argument	Students are given an explanation of a physical phenomenon i.e. day and night are caused by a spinning Earth, and a number of data statements (typically 4). They then have to discuss which data statements provides the strongest explanation for the phenomenon and provide an argument why. This is an idea that has been adapted from the innovative work of Garratt and colleagues (Garratt, Overton & Threlfall, 1999) in undergraduate chemistry.
8. Predicting, Observing and Explaining	This activity, drawn from the work of White and Gunstone (1992), involves introducing a phenomenon to children without demonstrating it and asking students to discuss in small groups what they think will happen when the phenomenon is initiated, and justify their reasoning. The phenomenon is then demonstrated and, if what happens is the antithesis of that expected, students are then asked to reconsider and re-evaluate their initial arguments. Discussion focuses on the theory that they advance for their prediction and the evidence to support it.
9. Designing an Experiment	Students are asked to work in pairs to design an experiment to test a hypothesis i.e. that a silver kettle cools faster. Their design needs to specify not only what variable should be measured but how often and what steps should be taken to ensure that the data obtained are reliable. Pairs then meet to discuss their design, to propose alternative procedures and to argue for their relative merits.

In Spain, the RODA Project ("roda" means wheel in Galician, and it is the acronym for "RazonamientO, Debate, Argumentación", or ReasOning, Debate, Argumentation) is a research programme carried out in the University of Santiago de Compostela, supported by consecutive grants from the Spanish Ministry of Science (which under some governments is collapsed with the Ministry of Education) since 1995. It is constituted by a set of classroom-based studies, and its focus has evolved from documenting the conditions for argumentation and the use of evidence, to supporting it through particular learning environments, to outlining learning progressions for argumentation in different disciplinary contexts. The target group are secondary school students, in both compulsory (12–16 year old) and upper secondary school (16–18 year old). However, given the difficulties for longitudinal studies in secondary schools in Spain (where optional subjects cause a rearrangement of groups every year), a three-year longitudinal study with primary school pupils (Jiménez-Aleixandre & López-Rodríguez, 2001; López-Rodríguez & Jiménez-Aleixandre, 2002) was also included. A substantial part of the publications from this project are in Spanish, including a recent book about argumentation and the use of evidence, directed to science teachers (Jiménez-Aleixandre, 2010), but here we will refer to the work published in English.

The RODA Project profiled three main features: first the collaboration among university-based researchers and secondary school teachers. Some of the studies can be framed in action-research or teachers' reflection on action, with a focus on teachers' performed action as the teacher-researcher was studying her or his own classroom (Mena, Sánchez & Tillema, 2009). A second feature is that argumentation is placed on a broader Inquiry Based Science Teaching (IBST) frame, and argumentation learning environments are considered a type of constructivist and IBST environments, with a specific focus on the development of epistemic practices and in particular on the evaluation of knowledge claims (Jiménez-Aleixandre, 2008). A third feature is that argumentation is promoted through engaging students in its practice, rather than by teaching it explicitly.

From a theoretical perspective, the RODA project frames argumentation in scientific practices or epistemic practices. Kelly (2008) defines epistemic practices as:

> "the specific ways members of a community propose, justify, evaluate and legitimize knowledge claims within a disciplinary framework. My argument is that an important aspect of participating in science is learning the epistemic practices associated with producing, communicating and evaluating knowledge." (Kelly, 2008, pp 99–100).

The three types of epistemic practices mentioned by Kelly are intertwined, and argumentation, as characterized in the RODA project, corresponds to the evaluation of knowledge. For these epistemic practices to occur, particular learning environments are needed (Duschl & Grandy, 2008; Jiménez-Aleixandre, 2008). Therefore part of the project's efforts went into designing teaching sequences and learning environments, in close collaboration with the teachers. These teaching sequences are organized around *authentic tasks*, dilemmas drawn from real life, that constitute problems which may have more than a potential solution, which are perceived as being relevant for students' lives and that require students to use inquiry procedures. Five instances of authentic tasks designed and implemented in the project are summarized in Table 3. A relevant constraint in the implementation of the teaching sequence was time, as teachers are concerned with covering all the topics in the Spanish curriculum. So the teaching sequences ranged from 17 sessions during several weeks, to four or five sessions.

Table 3. Instances of authentic problems from the RODA project (from Jiménez-Aleixandre, 2010, translated). Teaching sequences detailed in the Spanish references.

Task, topic, grade	*Problem (summary)*	*References*
Why are farm chickens yellow? Topic: Genetics 9th Grade (14–15 year old)	To explain why farm chickens are born with yellow feathers, instead of the spotted brown of chickens living in the wild. The fictional context is a request from the farm.	Jiménez-Aleixandre, Bugallo & Duschl (2000).
Evaluating environmental management in a wetland Topic: Environmental balance in ecosystems 11th Grade, night shift (16–21 year old)	The Environmental department of the Galician government solicits a report about the construction of a sewage network of underground drain pipes, as part of the project to clean the wetland from pollution. The project combines cleaning benefits and negative impacts on fragile habitats.	Jiménez-Aleixandre & Pereiro-Muñoz (2002). (In Spanish, Aznar & Pereiro, 1999, *Alambique*, 20)
Rescuing the U201-Wolf submarine Topic: Flotation 10th Grade (15–16 year old)	The Vigo city council is opening a competition to get a submarine afloat. The U201-Wolf submarine sunk duringthe 2nd World War. The students need to build a model submarine, to sink it and to get it afloat.	Bernal, Álvarez & Jiménez (1997) Ao rescate do U-201 Wolf: unha experiencia no proxecto RODA. *Boletín das Ciencias* 32: 61– 66. (Galician)
Choosing a heating system Topic: Energy and its uses 12th Grade (17–18 year old)	The University of Santiago de Compostela solicits a report about a heating system and energy sources for the new Medical School. Criteria include having low environmental impact and low cost.	Jiménez-Aleixandre, Eirexas & Agraso (2006). NARST meeting, San Francisco. Jiménez-Aleixandre et al. (2009) in www.rodausc.eu (In Spanish Federico et al., 2007, *Educatio*, 25)
Is it ecologically more sustainable to eat salmon or to eat sardines? Topic: Energy flow and trophic pyramids in ecosystems 10th Grade (15–16 year old)	Students are a NGO helping in a small seaside village after a tornado that destroyed harvests. For some time they should feed on fishing resources. They should design a plan for feeding more people for as long as possible, choosing among fishing mainly sardines and herring or mainly salmon.	Bravo-Torija & Jiménez-Aleixandre, (2012). Modeling marine resources management. (In Spanish, Bravo & Jiménez, 2010, *Alambique*, 63)

The publications of the project combine research papers in English or Spanish, focusing on the findings about argumentation practices, with papers in Spanish and Galician journals with the goal of offering resources for teachers. Some of the teaching sequences are also uploaded to the project website, www.rodausc.eu.

In terms of research focus, the RODA project began by addressing the complexity of classroom discourse by means of a holistic approach, acknowledging the different dimensions that need to be taken into account. Jiménez-Aleixandre et al. (2000) examine the intertwined dimensions of argumentation, epistemic operations (such as definition, appeal to analogy, appeal to consistency) and the 'doing the lesson' / 'doing science' distinction. 'Doing the lesson' is characterized as fulfilling the expectations about what is enacted in school, and 'doing science', as engaging in the production, communication or evaluation of knowledge claims. A goal of argumentation learning environments would be to move classroom discourse away from 'doing the lesson' and towards 'doing science', knowledge evaluation and argumentation.

Students' argumentation is explored in this project in connection with science learning, for instance, the process of data construction by secondary school students, engaged in identifying an unknown sample through the microscope, is examined by Jiménez-Aleixandre, Díaz and Duschl (1999). In order to match their observations with the four options for a suspect of stealing laboratory equipment, students interpreted and reinterpreted their observations in the process of appealing to empirical data to back their claims. The authors understand these shifting interpretations as a process through which data are constructed: 'data' are not equivalent to observation, but to the way these observations are interpreted. Figure 3 summarizes these steps in a students' dyad.

Data construction and argumentation are intertwined, the existence in the sample of one or two cell types is what counts for the students as evidence for their choice of the suspects.

The quality of 4th grade students' arguments along 10 sessions is analyzed in Jiménez-Aleixandre, López and Erduran (2005), as a part of a three-year longitudinal study about argumentation and environmental education from 4th to 6th grades (9 to 12 years). Pupils were required to decide upon the issues to study, the methods and in particular about the behaviour code in a field trip (Jiménez-Aleixandre & López Rodríguez, 2001). The quality and sophistication of students' arguments including rebuttals, rises the question of what features in the classroom environment supported the development of argumentative skills. It is suggested that the sustained enculturation in this particular school and classroom culture provided the environment adequate for argumentative competencies to develop.

Some of the studies in the RODA project examined argumentation in the context of socio-scientific issues. Jiménez-Aleixandre and Pereiro (2002) report about students' collaborative construction of arguments on environmental management in a wetland close to their school. In order to produce their reports about the pros and cons of a sewage network in a polluted area, the students worked with real data sets, maps, and technical projects. An interesting finding is how part of them changed their positions during the 17 sessions, as well as the justifications they gave for the changes (Jiménez-Aleixandre & Pereiro, 2005). In this study students were engaged with a real issue that was causing a social controversy and was significant for their engagement as citizens with scientific issues of social relevance.

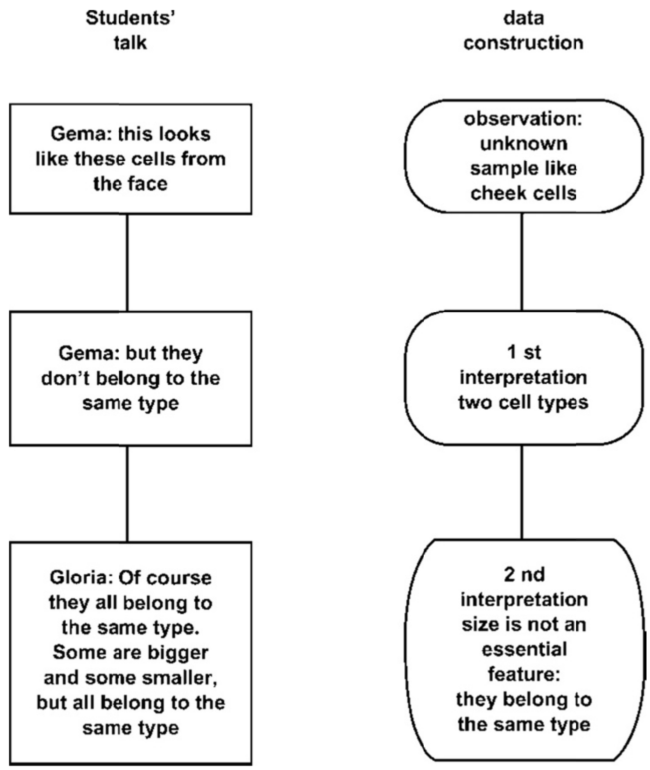

Figure 3 Process of data construction (from Jiménez-Aleixandre, Díaz & Duschl, 1999, modified).

The work of Fins Eirexas (Jiménez-Aleixandre, Eirexas & Agraso, 2006) focuses on a SSI related to energy use and sustainability. Working in groups, students were asked to select a heating system and appropriate energy sources for the buildings of the new Medical School in the University of Santiago de Compostela. Their options needed to meet the criteria of the USC's Environmental Efficiency Plan: low environmental impact and low economic costs. As with the problem about environmental management, there was not a single 'right' solution, a feature that promoted argumentation. The students' reports and their oral debates were analyzed for the epistemic levels in arguments, as well as for the meanings given to concepts as environmental impact and sustainability. The process of decision-making about this same problem of heating systems, by undergraduate students, has been examined in Gurutze Maguregi's doctoral dissertation (Uskola, Maguregi & Jiménez-Aleixandre, 2010). In this study the focus is on the criteria that students utilised to make their choices, and whether or not they considered evidence that was contradictory with their selected option.

Currently the project research focus is on the influence of the different argumentation contexts in the discursive processes and epistemic practices involved in argumentation. Two doctoral studies framed in this issue are those of Blanca Puig and Beatriz Bravo, and the SSI in both of them share a feature: causal explanations are relevant for engaging with the problems, besides ethical or environmental values. Puig and Jiménez-Aleixandre (2010, 2011) examine students understanding about the influence of environment in gene expression, and their positions in relation to biological determinism. In this context, a relevant argumentative process is the identification of evidence or justifications supporting a given claim (for instance a determinist claim about differences in intelligence between races). The authors use the didactical transposition perspective to explore how two teachers taught the model of gene expression and how they dealt with determinism. Bravo and Jiménez-Aleixandre (2012) examine students' participation in the epistemic practices related to modeling and argumentation, while working in a teaching sequence about marine resources management. The study explores how students connected the theoretical model of energy flow, on the one hand to the expressed model, and on the other to the physical world of living beings and actual data from the problem, and how they addressed the issue of sustainability.

As illustrated by these studies, the RODA project goals seek to combine the design of learning environments to promote IBST and argumentation, with the achievement of scientific literacy, that is with an interest in examining both students' engagement in argumentation and in meaning-making. We agree with Wickman and Östman (2002) in conceiving learning as discourse change, achieved as students become participants in new epistemic practices.

INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) AND ARGUMENTATION

There have been numerous research and development initiatives across Europe to integrate information and communication technologies (ICT) in science education (Kyza, Erduran & Tiberghien, 2009). Some of these initiatives have aimed to support the teaching and learning of argumentation in science classrooms at secondary school level (Monteserin, Schiaffino & Amandi, 2010). A key rationale for the choice of argument and argumentation as a genre in ICT has been based on the notion that learning activities should confront cognition and its foundations (Andriessen, Baker & Suthers, 2003). In this sense, substantial amount of research has been dedicated to how best to scaffold argumentative processes ranging from generating to justification of claims. An aspect that has often been neglected is the minimal attention given to the linearization process and linguistic aspects which are partly due to difficulty in incorporating ideas into the structure demanded and rhetorical goals (Brassart, 1996, Akiguet & Piolat, 1996). In an overview of the scaffolding tools in science teaching and learning, Kyza, Erduran and Tiberghien have summarized the following key aspects of tools that range from scientific visualization tools, databases, data collection and analysis tools, computer-based simulations, and modeling tools (Kyza et al., 2009, pp. 126–128).

Several trends can be detected in the use of ICT in argumentation in schooling across Europe. First, the incorporation of argumentation principles into ICT has been a multi-disciplinary effort across Europe at times involving cognitive psychologists, artificial intelligence experts as well as educators. Some of the key contributors to this interdisciplinary approaches have been funded by the European Union, including projects such as Kaleidoscope (Balacheff, Ludvigsen, de Jong, Lazonder, Barnes, & Montandon, 2009) and ESCALATE (Schwartz & Perret-Clermont, 2008). Second, some of the key research and development projects focused exclusively on science education have used US-based systems and models in their adaptations and development of tools to support argumentation. For example, the Viten (Jorde et al., 2003) and Argue-Wise (Evagorou & Osborne, 2007) projects relied on the principles of the WISE project developed at University of Berkeley in the USA (Linn & Hsi, 2000). Yan and Erduran (2008) have investigated the student-teachers' perceptions of the Belvedere Program developed in the United States by Brian Reiser and colleagues at Northwestern University.

Another trend in the use of ICT in argumentation research has been the contextualization of argumentation in scientific enquiry processes. The ESCALATE project capitalizes on two environments that mediate argumentation and inquiry-based practices (Schwartz & Perret-Clermont, 2008). Argumentation is enabled by the Digalo tool that has been developed in the earlier DUNES project also funded by the European Union. The Digalo tool provides a graphical platform in which participants may collaboratively construct an argument (on one computer or on different computers in a-synchronous mode) or participate in synchronous discussions. The argumentative map produced during the construction or during the discussion is an artifact that participants can exploit in further activities, as opposed to face-to-face discussions from which students cannot "physically" extract previous outcomes.

A further aspect of the argumentation work related to the incorporation of ICT tools has been the adaptation and/or extension of American-based systems. The COSAR (Computer Support for Collaborative and Argumentative Writing), for instance, has used features similar to the Belvedere program. COSAR is an all encompassing tool that supports idea-generation, planning and structuring, text composition and linearization in a collaborative environment (Erkens, Kanselaar, Prangsma, & Jaspers, 2002). It has an individual note area, a chat, a shared text editor for collaborative writing, a diagram tool for "for generating, organizing and relating information units in a graphical knowledge structure comparable to Belvedere" (Erkens et al., 2002, p. 16) using the 'box and link' approach to generate, relate and visually distinguish the simplified components of the argumentation produced (information, position, argument pro, support, argument contra, refutation, and conclusion). One of the important findings of this line of work has been that the planning tools "stimulate a more structured dialogue" (Erkens et al., 2002b, p. 125). The research team also found that argumentation on content, coordination, and metacognitive strategies is related positively to text quality, whereas argumentation on technical aspects of the task and on non-task related topics is related negatively to text quality(Erkens et al., 2002, p. 125).

Argue-WISE is another example of the adaptation of an American software design in application to the European context (Evagorou & Osborne, 2007). It is an online learning environment, which is geared towards key stage 3 and 4 students

(12–16 year-olds), designed within the WISE platform, which makes use of both knowledge representation and discussion-based tools. WISE (Web-based Inquiry Science Environment) is a knowledge integration platform designed by Marcia Linn and her group at the University of California, Berkeley. Evagorou and Osborne argue that the design of such a technology-enhanced environment provides scaffolds for argument construction by making thinking visible, making the structure of argument construction explicit, and structuring both peer-to-peer and group discussion. One of the main goals of Argue-WISE was to design and implement a learning environment to enhance young students' argumentation skills within the context of a controversial science topic and to evaluate the way in which their arguments develop. The design of Argue-WISE is based on the principles of project-based learning: a guided-discovery approach that invites students to work in groups and search for information in order to address a question, usually associated with an authentic everyday problem.

Similar to Argue-WISE, the Viten Project (http://www.viten.no) is a Norwegian research and development project (Jorde, Strømme, Sørborg, Erlien, & Mork, 2003) based on the WISE platform, providing a web-based platform with digital learning resources in science for secondary school. Students in grade 8–12 can work collaboratively on various science topics and each topic range s in duration from 2- 8 science lessons. Three types of programs are available, that engage students in: a) designing solution to problems, e.g. design a greenhouse for growing plants in a spaceship on its way to Mars, b) debating controversial issues, e.g. whether or not there should be wolves in the Norwegian wilderness, c) investigating scientific phenomena, e.g. radioactivity, gene technology. Mork's contribution to the field of science education from this study is a dual approach to analysing argumentation that takes both structure and content into account (Mork, 2005b). The dual approach functioned well as a tool for analysing student utterances and shows that student arguments varied from simple claims, to more elaborated arguments where reasons for claims were backed up by evidence and comparisons or examples. The most elaborated arguments also seem to be associated with correct content however, correct content is also found in less complex arguments. The majority of the utterances in this study contain correct or partly correct content, and students draw on biological, personal/social, political and economic information in their arguments.

ARGUMENTATION IN PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS

There is vast amount of research literature in science education in Europe that has extended the work of some American educators. A significant line of work relies on models of professional development based on Lee Shulman' notion of teachers' "pedagogical content knowledge" (e.g. van Driel, Jong, & Verloop, 2002). Other approaches to teacher education have extended the work of educational psychologists such as Diane Kuhn in application to science education (e.g. Zohar, 2004). In the context of argumentation, advocates for effective professional development have argued that the teaching of argumentation requires a model of pedagogy that is based on knowledge construction as opposed to knowlege transmission (Simon & Maloney, 2006; Zohar, 2008). Teachers' enculturation into new models of pedagogy to support argumentation requires systematic and long-term professional development (Simon, Erduran, & Osborne, 2006).

Few studies have been conducted in Europe that traced the development of science teachers in argumentation in a longitudinal fashion. Erduran & Dagher (2007) studied the development of two middle-school science teachers who participated, over 5 years, in various school-based research projects on argumentation ranging from basic research in teaching and learning to the development of professional development programs for training teachers in argumentation. The projects took place between 1999–2004 in the United Kingdom funded by the Economic and Social Research Council (Osborne, Erduran & Simon, 2004a), Nuffield Foundation (Osborne, Erduran & Simon, 2004b) and the Gatsby Foundation (http://www.cpdthroughpoe.com/index.html). The teachers were asked to reflect as a pair on various aspects of teaching and learning of argumentation. The results address the teachers' views and knowledge of argumentation, their perceptions of the goals, constraints and successes in their teaching of argumentation, their perceptions of themselves as learners and teachers, and their reflections on the professional development that they received.

Both teachers displayed sophisticated understanding of argument as well as its teaching and learning. Their recommendations centred around effective professional development to take into account a holistic presentation of teaching scenarios and a range of student abilities. Both teachers indicated that their own success with the project was due to their persistence in learning something new and the nature of the workshops conducted with them and other teachers – which have been summarized, trialled and published subsequently (Osborne et al., 2004a; 2004b). They also indicated that among many teaching strategies, they are now more conscious of doing group work and they view the ability to conduct and coordinate group discussions as a significant skill that can be transferred to other aspect of teaching. When asked to reflect on what kinds of developmental and cognitive skills they would expect students to undergo in the learning of argumentation, both teachers referred to a scheme used in the research project to analyze the quality of student argumentation in group discussions. The scheme derived from a theoretical account of argument based on Toulmin's work (1958) focussed on the use of rebuttals and the use of data and warrants to support one's claim while another person is in opposition to an original claim. Both teachers, whose classroom practices included meta-level language with students about the nature of rebuttals (Simon et al., 2006), indicated that a development in argumentation skills would necessitate the presence of improved skills with rebutting an argument. Teaching of and professional development in argumentation can pose numerous challenges. Curricular goals can hinder the effective implementation of teaching and teacher training if they are not in line with the learning outcomes intended by innovative pedagogical approaches such as argumentation (Erduran, 2006). A further component of complexity in the implementation of effective professional development programmes can be the diversity of interpretations of the national curricula. For example in England and Wales context, the exam boards such as EdExcel and OCR interpret the National Curriculum policy level statements for the design and implementation of teaching. Different exam boards tend to have different interpretations of the "How Science Works" (HSW) agenda, hence the use of argumentation in teaching. There is a review of some of the key exam board specifications on HSW component of the National Science Curriculum in England and Wales in Lavelle & Erduran (2007).

An important distinction to be made in teachers' professional development in argumentation concerns the contrast of pre-service teacher education (TE) and in-service teacher' professional development (PD). In numerous part of Europe, the models of TE rely on the inclusion of mentor teachers in the training of pre-service trainee teachers (e.g. Simon & Maloney, 2006; Erduran, 2006) typically involving both higher education-based training and school-based practical experience. The provision for PD of in-service teachers tends to be more sporadic with few comprehensive trends. In England and Wales, the Science Learning Centres have been instrumental in the delivery of professional development on the HSW component of the curriculum in a systematic way.

In England and Wales, there has been a renewed interest in the incorporation of themes that focus on knowledge construction as opposed to knowledge transmission. The recent revisions in the national science curriculum highlight a recognition that the teaching of science aims not only at conceptual outcomes of science but also the processes of scientific inquiry and communications. The "How Science Works" (HSW) component of the Science National Curriculum (DfES/QCA, 2006) suggests the incorporation of evidence-based reasoning and argumentation in various aspects of science teaching and learning. For instance, not only should pupils learn about coordination of evidence and explanation but also they should be communicating arguments (Table 4).

2006 National Curriculum: How Science Works	
Curriculum descriptor	*Argument skills*
Data, evidence, theories, explanations	Understanding the nature of evidence and justifications in scientific knowledge
Practical and inquiry skills	Justifying procedures, choices for experimental design; generating and applying criteria for evaluation of evidence
Communication skills	Constructing and presenting a case to an audience either verbally or in writing
Applications and implications of science	Applying argument to everyday situations including active social, economic and political debates

Table 4. How Science Works in the Science National Curriculum and potential target skills in argument (from LaVelle & Erduran, 2007).

Whilst policy and research recommendations unite in promoting argumentation in science classrooms, significant gaps remain between educational policy, research and practice in the context of inquiry teaching and in argumentation in particular. Provision for professional development in argumentation is still quite rare (Cetin, Erduran & Kaya, 2010; Zohar, 2008). One approach that has aimed to transform research and policy findings for professional development purposes is the project called *"Mind the Gap: Learning, Teaching and Research in Inquiry-Based Science Teaching"* funded by the European Union (Erduran & Yan, 2010). The project supported 6 in-service teachers from four schools in England to explore the policy and research aspects of argumentation in their classrooms. The programme was implemented in 2008–2009 with six secondary science teachers from four schools near Bristol, England in collaboration with researchers from University of Bristol. In infusing ideas about argumentation into professional development of science teachers, the Bristol team used an evidence-based approach applying some of the key outcomes of research on teacher education. For example, the work of Supovitz and Turner (2000) guided the model of professional development where it was deemed important to engage participants in inquiry, questioning and experimentation in a collaborative manner. Furthermore, the Project relied on the principles of teachers' collaborative exchanges with peers and reflective inquiries into their own teaching. The teachers were recruited by writing to schools about potential involvement in the project and the participating teachers volunteered to join. They were primarily mid-career teachers who specialised in chemistry and physics. Each workshop had input (a) by researchers, in terms of evidence from research evidence on the teaching of argument, and (b) by teachers, in terms of classroom learning and teaching practices. Variety of activities and formats were employed including group discussions and presentations. The professional development aspects of the project are summarised in a DVD (Erduran & Yan, 2009). The clips range in how the teachers addressed the curriculum policy context to the strategies used to support professional development such as evaluating and reflecting on peer teaching. The project teachers indicated a range of ways in which the project has facilitated their professional development. A set of themes suggested by the project data (Erduran & Yan, 2010, Erduran, 2012) are as follows:

Exchange and Communication

"Teaching to some extent, is quite a lonely journey," said by one of the teachers. The teachers appreciated the opportunity to exchange experiences and communicate with the teachers across different schools with different experiences and backgrounds. Furthermore, the friendly environment in the workshops encouraged the participants to critically and reflectively comment on each other's work.

Ownership and Engagement

The participants enjoyed this teacher-oriented programme that focused on their interests or issues. They felt supported to explore their interests in their own teaching situations. The sense of "ownership" motivated them to take on the initiatives. As one of the teacher said, *"it is like to [what we need to] do with the students, this open project allows us to do what we are interested in."*

Clarification and Justification of Curricular Policy

The teachers appreciated this programme for clarifying the justification of the policy initiative from the trainer's introduction and guided peer discussions. As one teacher said that, *"if teachers only see HSW as one of the policy changes in the curriculum, they won't bother to think seriously about it, never mentioned to take on initiative to teach differently in the class."* During the workshops, the teachers had a better idea about the reason why HSW was introduced to the curriculum and what would be the benefits of teaching and learning of science via argumentation. Through the exploration of the gaps between the policy and teaching practice, the teachers' awareness of the issues was raised. They indicated that their understanding of the HSW and argumentation has also been improved through the dynamic discussions in the workshops. Furthermore, the teachers' discussion and sharing has made the idea of HSW clear, explicit and practical in practice.

Awareness of the Role of Argument in Teaching Science

Teachers were appreciative of the infusion of research outcomes in the workshops. They indicated that the teacher's perception of the importance of argumentation might affect their motivation to teach argumentation and their lack of experience might be the obstacle as well. The resources shared by other teachers in the workshops extended their personal experiences and opened up reflective discussions. As one teacher explained, she *"realized that teachers need to model argumentation structure that pupils would understand."*

The work of argumentation in professional development in the Mind the Gap Project has been extended in the S-TEAM Project (Science Teaching Advanced Methods) funded by the European Union. One of the strands of this project has been led by Universidade de Santiago de Compostela (USC), in association with the University of Bristol and the CNRS, Lyon, France. The project will provide resources and strategies to help teachers to create learning environments for argumentation and the learning of discursive practices in science. A key priority of the S-TEAM Project is to disseminate training resources and classroom materials to support the teaching and learning of argumentation in science classrooms and the development of teachers' reasoning about the nature of scientific knowledge. A professional development programme has been designed and implemented to promote coherence and growth in teachers' skills in these aspects. Outcomes in terms of students' argumentation skills will provide proof of the effectiveness of professional development interventions.

One of the outcomes of the S-TEAM project is a report on argumentation and teacher education in Europe (Jiménez-Aleixandre et al., 2010). Intended for policymakers and other stakeholders in education, it seeks to share information about the development of argumentation in Europe. The report's purpose is to review the state of the art about argumentation in Europe, particularly in the 15 countries involved in the project and to draw on published research to suggest lines of improvement. It explores argumentation through three dimensions: policy documents, initial teacher education and teacher's continuous professional development (CPD). We will briefly summarize some results about CPD, although it needs to be noted that responsibility for CPD is attributed to different instances in different countries, from the Ministries of Education, to teacher centres or local authorities, making difficult to draw common pictures of such a complex situation.

Jiménez-Aleixandre et al. report that argumentation is currently part of CPD programs in 13 countries; that is all but two, although with a great diversity in weight and format. The differences range from explicit presence in goals and content, to being embedded in broader topics, such as competences, IBST or reasoning. Even in the case of half of these countries, where argumentation is integrated in CPD in the frame of national programs, the course contents exhibit a great deal of variation, from explicit modules about argument construction and examples of activities to introduce it in the classrooms, to a presence embedded in reasoning, communication or debate.

The report also explores the availability of resources for teachers who may be interested in introducing argumentation in their science classrooms. About this issue there are also great differences, but the data point to an increasing availability of resources. For instance, in Denmark there is a wealth of available resources for teaching argumentation, which suggests a continued interest in the topic in CPD initiatives.

The report points out to some data showing the impact of European projects on the uptake of argumentation in teacher education. One instance may be the introduction of argumentation and IBST in CPD programs, as an effect of S-TEAM, in all the Ministry of Education summer courses in Spain targeted for science teachers. Another is making accessible resources for teaching argumentation, as illustrated by the use of the Mind the Gap resources in England and Wales, Spain and Denmark.

In the University of Santiago de Compostela, the researchers involved in the RODA project viewed the participation in EU projects as an opportunity for directing their attention to making their research accessible for teachers. This is the key idea behind the Mind the Gap project, to bridge existing gaps between research and schools. One of the main resources used both in initial teacher education and in CPD courses in Spain is an argumentation booklet (Jiménez-Aleixandre et al., 2009) produced within Mind the Gap, as well as other resources available in the USC web (www.rodausc.eu). Teaching sequences for argumentation in teacher education, and teachers' guidelines produced in the USC in cooperation with teachers in the S-TEAM project, have also been used in CPD courses. This approach seeks to combine in-depth work with a small focus group with dissemination to the wider community of science teachers. At the University of Bristol, researchers (Erduran, Ingram & Yee, in press) have been producing the professional development approaches and teaching resources on argumentation and its relation to practical work, to be published for wider dissemination in England.

FUTURE DIRECTIONS FOR RESEARCH ON ARGUMENTATION IN SCIENCE EDUCATION IN EUROPE

Our review indicates that cross-national collaborations on argumentation work in science education have already been established across Europe, particularly through projects (e.g. Mind the Gap and S-TEAM) funded by the European Union. There have also been personal collaborations that have led to some insightful syntheses of work across national boundaries, for instance through research visits between academics (e.g. Evagorou et.al., 2012, von Aufschnaiter et al., 2008). However the emphasis of work has been mainly national, not cross-national. Further research and development would be fruitful particularly in comparative analysis of argumentation in different national contexts, an area of work that is scarce. In one study, Castells and colleagues compared the argumentative schemes of primary science trainee teachers' arguments as well as their ideas, conceptions and beliefs on which they base their arguments (Castells, Konstantinidou, & Erduran, 2010). The study was the result of a project funded by the Anglo-Catalan Society and conducted in Barcelona and Bristol. The project included analyses carried at three levels. At the first level, the researchers compared the number of arguments by tasks and by country. At the second level, they analysed arguments and made a comparison between types of argumentative schemes by tasks and by countries. More in depth, qualitative descriptions were carried out in order to illustrate the similarities and differences between the Catalan and English primary student-teachers' arguments and scientific conceptions. Results illustrate that the arguments generated by students are quite similar in both samples in terms of number of arguments and frequencies of types of arguments, but with some differences in the order of these frequencies related to specific tasks. More relevant is the qualitative difference in the way that appeals are made to give evidence and theories, given the identification of premises and argumentative schemes; this favours good understanding of scientific knowledge. Future studies could build on these efforts to gain a deeper appreciation of the cultural and national factors that impact teachers' and learners' argumentation in science classrooms.

Related to the domain of cross-national work, it should be noted that language and language politics are key elements to consider in science education research efforts in Europe. Considering Europe is diverse in languages and cultures, the language variation and its influence on the way that argumentation is taught and learned in the classroom cannot be underestimated. This is particularly relevant for work related to the linguistic aspects of argumentation and the way in which arguments are constructed. There is currently no research dedicated to the learning of argumentation in bilingual and trilingual settings and the way in which arguments interact within and across different languages. Parts of Europe such as Luxembourg and the Netherlands where there is bounty of trilingual schooling (Baker, 2006), there is much potential to investigate the ways in which language variation has an impact on the nature and quality of argumentation.

An aspect of argumentation research that has not been addressed sufficiently in the literature is the relationship between disciplinary content or conceptual knowledge and argument structures and processes. Detailed studies of the relationship between argumentation and the development of scientific knowledge are rare. Jimenez-Aleixandre and Pereiro-Muñoz (2002) found that the involvement of 17- to 21-year-old students in argumentation and decision making about environmental management resulted in them becoming knowledge producers, not because they created new knowledge, but because they applied knowledge to practical contexts, combined ecological concepts, and integrated conceptual knowledge with values. Aufschnaiter and colleagues (2008) have used video and audio documents of small group and classroom discussions to analyse the quality and frequency of students' argumentation using a schema based on the work of Toulmin (1958). In parallel, students' development and use of scientific knowledge was also investigated, drawing on a schema for determining the content and level of abstraction of students' meaning-making. These two complementary analyses enabled an exploration of their impact on each other. The microanalysis of student discourse showed that: (a) when engaging in argumentation students draw on their prior experiences and knowledge; (b) such activity enables students to consolidate their existing knowledge and elaborate their science understanding at relatively high levels of abstraction. The results also suggested that students can acquire a higher quality of argumentation that consists of well-grounded knowledge with a relatively low level of abstraction. The findings further suggest that the main indicator of whether or not a high quality of argument is likely to be attained is students' familiarity and understanding of the content of the task.

A related problem in the argumentation literature is the question of whether or not students engage in meaningful argumentation not just about science concepts but also about socio-scientific issues and whether this process improves their conceptual understanding of science. In a recent study, the Australian researchers Venville and Dawson (2010) investigated the impact of classroom-based argumentation on high school students' argumentation skills, informal reasoning, and conceptual understanding of genetics. Their findings showed that following an invervention study, the argumentation group, but not the comparison group, improved significantly in the complexity and quality of their arguments and gave more explanations showing rational informal reasoning. Both groups improved significantly in their genetics understanding, but the improvement of the argumentation group was significantly better than the comparison group.

Considering the often culture-specific orientation to socio-scientific issues, it would be worthwhile to extend such studies on the interaction between socio-scientific issues, argumentation and scientific knowledge to European countries where language, culture, society, history among other factors are diverse in national contexts.

The study of disciplinary nuances in the subject knowledge itself holds the potential for novel approaches to understanding science education in general and argumentation in particular. The case for domain-specificity and scientific knowledge has been made by cognitive psychologists (e.g. Shunn & Andersson, 1999) and philosophers of science (e.g. Scerri, 1994) for some time. Yet the uptake of this work in science education has been minimal even though disciplinary knowledge can propose particular suggestions for how argumentation can be contextualised in science, as illustrated with a chemistry example briefly revisited here but reported more extensively elsewhere (Erduran, 2007). In school science it is typical practice to emphasize the nature of the Periodic Law within groups of elements in the sense that the elements are assigned similar chemical properties. For example, the properties of alkali metals in water are used to illustrate the increase in reactivity as one goes down the Group 1 Alkali Metals. However students are rarely given the opportunity to argue the case for the approximate nature of trends Thorium, whose valence electron configuration is d2s2 is not placed in IUPAC group 4 with the only other three elements that share this configuration (Ti, Zr and Hf) but rather a group of actinide elements where its only vertical relationship is with Ce, configuration fd2. Meanwhile, IUPAC group 10 contains just three elements with three different valence electron configurations: Ni d8s2, Pd d10 and Pt d9s1. The lack of a universal system of placement of elements in the Periodic Table creates an opportunity for argumentation when the predicted elements do not fit into the observed placements, raising key issues about how knowledge gets constructed and represented in chemistry. Other sciences will pose their own disciplinary orientation to how concepts are problematised and situated in the broader body of knowledge including developmental aspects of learning (e.g. Keil, 2007).

Erduran and Pabuccu (2012) have taken such a disciplinary orientation in situating argumentation in teaching and learning in the context of stories. The resources for teachers and students aim not only to promote argumentation in the discipline of chemistry but also to aid motivation in science in general through engagement by embedding the chemical concepts in interesting contexts.

Despite wealth of research in classroom-based research on argumentation since the mid-1990s, our review suggests that the territory remains ripe for numerous lines of work in the future. Among these, there is surprisingly little dedicated to the exploration of students' and teachers' perceptions of argumentation (e.g. Kaya, Erduran & Cetin, 2010). Likewise, developmental trajectories of teachers in learning argumentation in a longitudinal fashion are virtually nonexistent (e.g. Erduran & Dagher, 2007). A fruitful new territory for argumentation research could draw from 'science studies' – the interdisciplinary studies on science with implications for science education (Duschl, Erduran, Grandy, & Rudolph, 2006).

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