Argumentation in Science Education: Perspectives from Classroom-Based Research

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Editors

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Dedication

To my parents, Ayten Erduran, whose life was evidence of compassion, courage and intellectual curiosity, and Erol Erduran, whose wisdom, intellect and humour justify his being the greatest educator I have known. (S. E.)

To my parents, María Pilar Aleixandre-Parra, who left me as heritage the thirst for knowledge, and Miguel Jiménez-Gan, who taught me that all claims should be reasoned and justified. (M. P. J.-A.)

Preface

Our conversations about arguments began in Nashville in the Spring of 1996 in Richard Duschl's doctoral seminar that we were both attending, Marilar Jiménez-Aleixandre as a visiting scholar at Vanderbilt University. Jiménez-Aleixandre and Duschl were designing authentic problems in genetics for the University of Santiago de Compostela-based RODA project aimed at engaging high school students in argumentation.

Erduran and Duschl had been working on Project SEPIA extending their work in Pittsburgh schools to the design of curricula that support epistemological aspects of scientific inquiry including argumentation. In that spring we attended a NARST session in St Louis, where Gregory Kelly, Steven Druker and Catherine Chen presented a paper about argumentation. As a consequence, a symposium about argumentation was organised (possibly the first of its kind) at the 1997 NARST meeting in Chicago, including papers from Kelly and colleagues and from Jiménez-Aleixandre, Bugallo and Duschl. The symposium was attended, among others, by Rosalind Driver, who had just submitted an application for funding of an argumentation project based at King's College London, a project Erduran would incidentally work on after Driver's untimely death.

From this time frame in the 1990s to the present day, argumentation studies in science education have increased at a rapid pace, from stray papers for which we were unable to find an appropriate strand in a conference, to a wealth of research base exploring ever more sophisticated issues.

Our intention in this book is to provide an account of the state-of-the-art research in the field. We are grateful to the leading scholars who contributed to the book and who engaged with us in productive interactions during the last two years. We are indebted to Larry Yore for plenty of good advice and to University of Santiago de Compostela who supported Erduran's visit to Santiago for one month, allowing us to work through the final stages of editing. We would finally like to acknowledge our respective universities (University of Bristol and University of Santiago de Compostela) as well as our publishing editor, Harmen van Paradijs at Springer for their support throughout the production of this book.

Foreword

This volume illustrates how argumentation in science education is involved in a variety of research studies and teaching sequences. Argumentation is involved in studies on communication, discourse, learning particularly those on high order thinking process, and epistemology as a component of the nature of science with internal and external perspectives, on citizenship education and more specifically those concerning socio-scientific issues. This list is impressive and at the same time heteroclite; then the question of how argumentation is situated in science education is raised.

A way of characterising this situation is to consider how argumentation intervenes in science education, as a component of teaching content or as a teaching process and how it is involved in education goals. More specifically argumentation can be (1) a part of the knowledge to be taught included in an official curriculum; (2) a way to help students to better understand the knowledge to be taught. These two aspects do not intervene in the science education goals with the same status. Consequently they do not have to be legitimated by the society or accepted by schools, teachers, students and their parents similarly. Moreover a part of argumentation as proposed by some of the authors of this book is not necessarily scientific argumentation, but also a citizen's argumentation and so it is beyond the disciplinary goals of education. Again, these different goals cannot be legitimated in the same way.

Analysing these different integrations of argumentation in science teaching and their associated goals allow us to be aware of the risks of limiting these integrations to interesting "experimental or innovative teaching sequence". For durable introduction of argumentation in science education. I propose two aspects to take into account:

- The processes of legitimising argumentation in science education
- The question of legitimising the citizenship education that is beyond the current acknowledged disciplines

Processes of Legitimating Argumentation in Science Education

In order to analyse these processes we use the theory of ecology of knowledge constructed by the French researcher Chevallard (1991). This theory is based on a view on knowledge. Knowledge "lives" within groups of people. These groups can be very diverse such as a class, a scientific community of researchers, a scholarly society, or a group of people dealing with environmental questions. The term "knowledge" in this perspective has a broad meaning: it is not limited to content, but includes paradigms, the embedded epistemology and also skills. A basic statement is that the meaning of a given element—like a formula, a principle or a description of an experiment—is not exactly the same when this element is used by different groups; each group constructs a "specific" knowledge. For Chevallard (1991), there is a fundamental reason for this specificity of meaning in a given group; this meaning is based on the relations between this element of knowledge and the other elements; in other words an element is not isolated but included in a set of knowledge. When an element (or subset of elements) is dissociated from the set in which it takes its meaning for a group (e.g., Genetically Modified Organisms, GMO, in the set of genetics for a group of biologists), and reinserted in another set that lives in a different group (GMO in a high school classroom), its meaning is necessarily modified. This modification of meaning due to change of groups in which "lives" an element of knowledge is named *transposition*.

Another basic statement is that knowledge involved in a curriculum should have a *referent* elsewhere than in the educational system. In traditional curriculum, the teaching goal of a discipline like biology, chemistry, or physics, is the acquisition of this discipline and the referent knowledge is the scientific knowledge of the scholarly communities. These communities legitimate the curriculum in the society eyes in a country. In vocational schools, legitimacy is mainly based on the professional communities. However nowadays, legitimacy from scientific communities can become less straightforward to the extent that science is put in question in our occidental societies (see for example ROSE results at students' level, Sjøberg, 2005), and that citizenship education is valued.

Legitimacy processes involving reference to scientific knowledge on the one hand and distance between the referent knowledge and the curriculum (transposed knowledge) on the other hand should be differentiated. For example two physics curricula can have the same referent knowledge in physics, be legitimated in societal eyes and, in the same time, include rather different contents. Transposition can correspond to a few or very deep modifications between the referent knowledge and the knowledge to be taught.

On the basis of this approach, I raise the question of the place of argumentation in the legitimacy process of a curriculum. How argumentation, as a part of the knowledge to be taught or of teaching processes is legitimated?

To study this question with the theory of ecology of knowledge, I propose to look for the type of teaching contents or curricula in which argumentation is involved, and to analyse their reference in legitimacy processes. As mentioned previously argumentation is involved in a variety of teaching contents with different goals. The overview given in the first chapter of this book (Jiménez-Aleixandre and Erduran) specifies them. Three main types of goals can be distinguished: developing students' knowledge and skills on the nature of science, developing students' citizenship in particular in the case of socio-scientific issues, and favouring learning, more specifically developing higher order thinking, in particular argumentation. In some countries, these different types of goals have started to be introduced in the official curriculum, in other countries they are forward thinking recommendations mainly done by researchers in science education and/or teachers. Whatever their status, the question of the references taken for these goals and their associated teaching content is raised.

Let us take the case of introducing "nature of science" in the teaching content. Its reference is easy to determine: the scientific disciplines and their epistemology. In fact, in comparison to traditional teaching, the reference is the same or is only extended. Reference is the same if we consider that the difference with traditional curriculum is due to the *transposition* process. In traditional teaching, nature of science is eliminated through this process. To specify what is eliminated, we refer to Tseitlin and Galili's (2005) analysis of a scientific discipline. They propose to decompose a discipline into three domains: nucleus, body and periphery. In the transposition process, the nucleus ("fundamental principles, paradigm and claims of meta-disciplinary nature", p. 243) is eliminated whereas the "body" is kept. The body incorporates "established knowledge, each item of which is based on the principles contains in the nucleus" (p. 243). Their analysis of standard physics textbooks confirms that these books mainly (and sometimes only) present "the body" of the discipline. In this framework, introducing nature of science into curricula means to introduce the nucleus ("fundamental principles, paradigm and claims of meta-disciplinary nature", p. 243). This usual elimination of the nucleus in the transposition process is frequently justified by considering that it is not understandable by students and difficult to teach and to assess.

Reference is extended towards two directions, first epistemology of science to analyse the "nucleus" and second sociology of science. This last case happens, when, in nature of science, the social practice of researchers is included as many authors of this book do it, in particular in reference to works of sociologists like Latour (Latour & Woolgar, 1979). Then, another scholarly society is involved: sociology of science. This extension could be rejected by the "hard" scientist communities, which consequently will not legitimate this new knowledge to be taught.

The goal associated to socio-scientific issues is less traditional because the main reference comes from the society and citizens problems, and not from the scholarly societies acknowledged to create and validate scientific knowledge. Legitimating such teaching goals is not easy; it assumes a consensus in the society of the country or the state, at the level where curriculum is decided. Nowadays this consensus is not obvious to reach in our society (Legardez & Simonneaux, 2006). Astolfi (2005) underlines that the ideological diversity in our contemporary societies makes risky the debate of socio-scientific issues. The question is raised to know if socio-scientific issues make running a risk to split up educational system to the extent that people have diverse and even contradictory expectations about it. The question of what can or cannot be debated in classrooms is opened and not easily answered nowadays. Argumentation is a way to get some distance vis-à-vis socio-scientific issues and thus helps to“a pragmatic arbitration of contradictories ideologies” (ibid. p.9).

The case of argumentation as “higher order thinking” is different from the others to the extent that, in the process of transposition, hypotheses on learning are involved. For example, Duschl (this book) makes explicit that these leaning hypotheses are introduced on the basis of “newer ideas and beliefs in cognitive and social psychology [that] speak to the importance of instructional sequences/units that seek outcomes related to students’ reasoning and communication in science contexts.” In fact, this case includes processes of teaching (involving high order thinking) and teaching contents either relative to nature of science or socio-scientific issues. This case makes the legitimacy process rather complex because the types of referent knowledge are multiple, in particular psychology and science education, physics, chemistry or biology, sociology, and each community of scientists can only legitimate some components of the teaching content. Only the representatives can legitimate the whole teaching content (in democratic societies). This case is complex and the durability of such teaching contents is questionable. My hypothesis would be that, for durability, the teaching practices and teaching content have to be strongly implemented in the different components of the school system (teacher training, programme, school practice, evaluation, etc.). In that case, teacher training and teaching resources are crucial. This book tackles these questions of designing teaching and learning environments including computer-enhanced learning environments, and more specific tools that can be used and accepted by teachers and students. A large range of tools, without forgetting assessment, and teacher training are necessary for durable implementation of argumentation in science education.

The Case of Legitimating Citizenship Education

Argumentation is a key element involved not only in the “scientific culture” of the citizen but more largely in a trans-disciplinary view of culture. To elaborate the knowledge to be taught leading to a scientific culture of the citizen, it is necessary to go beyond the scientific disciplines. Examples like the social questions of GMO, mobile phones, or black tide, involve economics, safety, and other issues. In some teaching perspectives, science is no more the goal but becomes a tool to help student to understand societal problems.

Figure F.1 illustrates the three different goals discussed previously with two examples. The first example deals with a teaching project situated within scientific domains of which goals are mainly related to “higher order thinking” and to nature of science (Duschl, this book). The second case deals with teaching projects directly linked with a main societal event: black tide of Prestige in Galicia (Jiménez-Aleixandre, 2006); the teaching goals come from the society, and the same society legitimates them. These examples show different distances between the goals and the teaching content designed to reach their goals. Let us note that, in traditional disciplinary curricula, the goals and the contents are similar, for example biology, chemistry or physics are taught with the goal of students' acquisition of these disciplines. In both examples of Fig. F.1, scientific disciplines are only "tools" to reach goals. In the first example, as we state in the first part, the references are disciplinary in terms of "nucleus" including epistemology of science and their legitimacy also includes learning hypotheses. In the second example the society legitimates its own reference and teaching content as tools to reach the goal refer to scientific knowledge.

In this second example the general goal deals with citizen culture. Sciences become tools to teach trans-disciplinary knowledge. In fact, most of the chapters of this book include more or less explicitly a component of citizen culture. The second case is illustrative of many studies that have to manage two views of argumentation: as scientific social practice and as social practice in the society.

Let us note that for the second view, usually there is no reference to argumentation as a branch of rhetoric, which could be a part of the culture and then be included in a pluri-disciplinary teaching content. A reason could be that the legitimacy of argumentation as a component of the scholarly discipline had difficulty during the 19th and first part of the 20th century and restarted to be developed after the Second World War "not only in French language (Perelman and Olbrechts-Tyteca) and in English (Toulmin), but also in German" (Plantin, 2005, p.14). In science education, researchers in their analyses use these scholar studies, as this book shows. But these research works on argumentation are not used as reference for curricula or innovative teaching content introducing argumentation with scientific literacy goal.

	1.SEPIA (Duschl, this book)	***2. Black Tide (Jimenez Aleixandre, 2006)***
Goal Goal of a teaching sequence (or a part of a curriculum)	Scientific reasoning Ability to reason about explanations, experiments, and models	Close environment of the students should be made intelligible to them
Tool (to reach the goal) For a teaching sequence (or a part of a curriculum)	Making exercise for healthy heart,etc. includes scientific content, reasoning, and higher thinking processes	Using environment and its problems as objects and resources for learning Many different types of activities and actions, some are teaching activities in science (physics, chemistry, biology)
Referent communities	**For goal**: Scholarly societies in epistemology and experimental sciences, and in psychology and science education **For tools**: Scholarly societies in experimental sciences, etc.	**For goal**: The society that decides the goal. **For tools**: A diversity of referents depending on the tools. Scholarly societies in experimental sciences, etc.

Fig. F.1 Two cases of analysis of teaching sequences (or learning environment) in terms of goals and teaching tools, and the referent communities from where they came

For the two examples given in Fig. F.1, the teacher's classroom management needs a rather high level of analysis of the different components involved in the studied situation and a certain level of competency on each of these components (e. g., epistemology, several experimental sciences). Figure F.2 shows that, when a social situation is more or less directly "imported" into the classroom, the teacher has a huge responsibility; it has to do most of the transposition in order that this transposed situation should be relevant not only for students' learning but also for what the society recognises as being worthwhile to teach at school. Among these multiple charges, the teacher has the responsibility to help the students to make clear (when possible) the different criteria to accept or reject arguments pertaining to experimental sciences, epistemology, or everyday life. Several contributions of this book propose typologies or categories of arguments; they illustrate that it is not easy to establish criteria to differentiate arguments.

The concept of transposition helps us to make explicit the heavy teacher charge (Fig. F.2). At the same time, nowadays introducing social knowledge and practice of debates as referent and as goal in curricula is a current tendency, however it addresses difficult questions that should be taken into consideration to be successful. Studies on argumentation in science education clearly contribute to make explicit and propose elements to implement curricula with such goals.

This book shows how argumentation is a very rich domain to investigate and contributes to improve science education. It is divided into three sections. The first section, devoted to argumentation foundations includes a very well informed overview (Jiménez-Aleixandre and Erduran, Chapter 1), which should constitute a reference for future research in our community. Chapter 2 presents a basic component of studying argumentation in science education: the cognitive (Garcia-Mila and Andersen), and Chapter 3 deals with methodological foundations (Erduran). The last chapter of this section (Sandoval and Millwood, Chapter 4) pertains to the epistemological component by tackling the challenging question of relation between students' argumentation and their epistemological ideas and their epistemic practices.

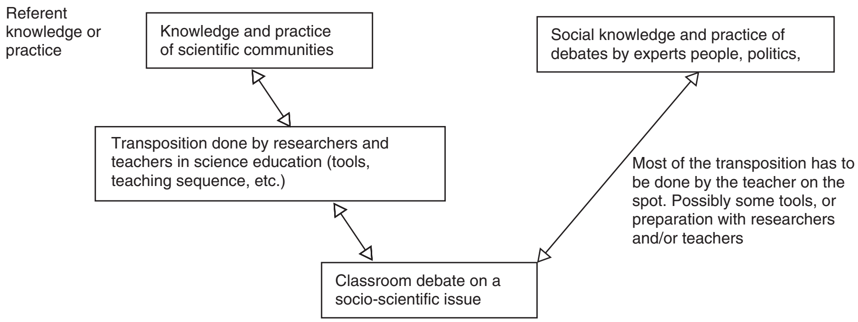

Fig. F.2 References of arguments involved during a classroom debate (scientific, social). These different arguments can appear quasi-simultaneously

The second section deals with teaching and learning argumentation. In Chapter 5, Jiménez-Aleixandre discusses the features of learning environments that promote argumentation in science classrooms and the necessity of work on design to develop argumentation. Chapter 6 (Kølsto and Ratcliffe) deals with the social aspects of argumentation, approaching the context in which argumentation is involved in classroom and the social aspects of the teaching goals. The two other chapters concern the nature and quality of students' argumentation. Kelly, Regev and Prothero, in Chapter 7, identify and analyse the nature of the claims being made by the student writers and how these claims are developed as the lines of reasoning supporting a thesis. Chapter 8 (Duschl) deals with the quality of argumentation and epistemic criteria on the basis of the analysis of students argumentation discourse and epistemic criteria used by middle school students.

The third section entitled argumentation in context includes four chapters introducing the readers to a large range of contexts for argumentation in science education. Chapter 9 (Simmoneaux) of this section is devoted to students' argumentation skills on socio-scientific issues like GMO in relation to the teacher's role. Chapter 10 (Zeidler and Sadler) deals with socio-scientific framework in the perspective of engaging students to reason about moral issues. In Chapter 11, the research field on the role of computer in education is involved. Clark, Stegmann, Weinberger, Menekse and Erkens present the case of computer-enhanced learning environments to support students' argumentation with fruitful results and perspectives. Chapter 12 (Zohar) deals with science teacher education a professional development in argumentation that is a crucial component in the introduction of argumentation in the teaching and learning of science.

Andrée Tiberghien

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Contents

Part I
Argumentation Foundations

Chapter 1
Argumentation in Science Education: An Overview

María Pilar Jiménez-Aleixandre and Sibel Erduran

Charles Darwin once described *On the Origin of Species* as "one long argument". This sentence can be viewed as embodying several of the different dimensions of argumentation discussed in this book. On the one hand, it provides evidence, coming from someone with undisputable authority, on argument being an integral part of the construction of scientific knowledge. On the other hand, when applied to the outstanding piece of scientific thinking that is *On the Origin of Species*, the description combines two aspects of argumentation. The first aspect relates to the justification of knowledge claims, by marshalling converging lines of reasoning (see Kelly, Regev, & Prothero, this book), theoretical ideas and empirical evidence toward a claim. Darwin weaved together population theory from Malthus, or uniformitarianism from Lyell, with empirical data gathered in his voyage to Central and South America in his bold claim of the theory of natural selection. A second aspect of argumentation has to do with argumentation as persuasion, in Darwin's case as an attempt to convince an audience, composed both of scientists and of the general public, that the animals and plants had changed, that the species living on Earth descended from other species instead of having being created all at a time. Darwin was well aware that the task of persuading his contemporaries was not an easy one, such awareness being one of the reasons for delaying the publication of his book for about twenty years. In fact a joint presentation by Darwin and Wallace in the Linnean Society in 1858 stirred little interest, and the president of the Society summarised the year as one that "has not indeed been marked by any of those striking discoveries which at once revolutionize science" (Beddall, 1968, pp 304–305). However, one year later, the publication of Darwin's book launched a great controversy, corresponding yet to another aspect of argumentation, as debate among two parties with contrasting positions on a subject.

Argumentation, in whatever sense it is conveyed, is an integral part of science and we argue it should be integrated into science education. In this chapter, we present an overview of a line of research in science education whose main purpose has been exactly such attempts to make argumentation a component of instruction and learning. Indeed the field on argumentation in science education has been receiving growing attention in recent years. Firstly we outline a rationale for why should we, teachers or science educators, promote argumentation in science classrooms. Second we discuss different meanings of argumentation and some

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approaches to its study, particularly those relevant for science education. In the third section we turn our attention to an overview of some themes from international policies for science curricula that provide a context and a rationale for the inclusion of argumentation in science education worldwide. We conclude the chapter with a brief link to some of the earlier work that formed the foundation of argumentation studies in science education. Overall, our discussion illustrates the theoretical, empirical and policy level conceptualisations in the study of argumentation in science education which point to the significance of research in this area.

Why Argumentation in the Science Classroom?

In recent years, a growing number of studies are focusing on the analysis of argumentation discourse in science learning contexts (e.g., Driver et al., 2000; Jiménez-Aleixandre et al., 2000; Kelly & Takao, 2002; Zohar & Nemet, 2002). These works draw, among others, from two related frameworks. One framework is related to science studies highlighting the importance of discourse in the construction of scientific knowledge (Knorr-Cetina, 1999; Latour & Woolgar, 1986) and consequences for education (Boulter & Gilbert, 1995; Erduran et al., 2004; Pontecorvo, 1987). A second framework is the sociocultural perspective (Vygotsky, 1978; Wertsch, 1991) which points to the role of social interaction in learning and thinking processes, and purports that higher thinking processes originate from socially mediated activities, particularly through the mediation of language. To these could be added an interest in democratic participation, which requires debate among different views rather than acceptation of authority. The implication is that argumentation is a form of discourse that needs to be appropriated by students and explicitly taught through suitable instruction, task structuring and modelling.

From these approaches a view can be derived about science learning in terms of the appropriation of community practices that promote the modes of communication required to sustain scientific discourse (Kelly & Chen, 1999; Lemke, 1990; Mason, 1996). Such a view stands in contrast to the traditional views of science learning that focus only on outcomes such as problem-solving, concept learning or science-process skills. Science learning is thus considered to involve the construction and use of tools that, like argumentation, are instrumental in the generation of knowledge about the natural world (Kitcher, 1988). Argumentation plays a central role in the building of explanations, models and theories (Siegel, 1995) as scientists use arguments to relate the evidence they select to the claims they reach through use of warrants and backings (Toulmin, 1958). The case made is that argumentation is a critically important discourse process in science, and that it should be promoted in the science classroom (Duschl & Osborne, 2002; Jiménez-Aleixandre et al., 2000; Kelly et al., 1998; Zohar & Nemet, 2002). A significant question, however, is why argumentation deserves to be promoted in the context of science learning. Put more specifically, what is the rationale for introducing argumentation in science learning?

Andrée Tiberghien (this book) frames this question in the theory of "didactic transposition" (from the French *transposition didactique*, where *didactic* does not have the standard English meaning of traditional approach, but the less charged significance of the original Greek "related to teaching", common to most Indo-European languages). Tiberghien discusses the external referents for the legitimisation of argumentation, distinguishing two aspects: one it's about the place of argumentation in science education and the other about the connections between argumentation and citizenship education. She summarises the place of argumentation in science education in terms of three goals: knowledge about nature of science; developing citizenship and developing higher order thinking skills. With an approach complementary to Tiberghien's exploration of external referents, in this section we elaborate on the rationale for argumentation appealed to from within the educational community, and particularly the science education community.

We propose that there are at least five intertwined dimensions or potential contributions from the introduction of argumentation in the science classrooms:

- Supporting the access to the cognitive and metacognitive processes characterising expert performance and enabling modelling for students. This dimension draws from the situated cognition perspective and the consideration of classrooms as communities of learners (Brown & Campione, 1990; Collins et al., 1989).
- Supporting the development of communicative competences and particularly critical thinking. This dimension draws from the theory of communicative action and the sociocultural perspective (Habermas, 1981; Wertsch, 1991).
- Supporting the achievement of scientific literacy and empowering of students to talk and to write the languages of science. This dimension draws from language studies and social semiotics (Kress et al., 2001; Norris & Phillips, 2003; Yore et al., 2003).
- Supporting the enculturation into the practices of the scientific culture and the development of epistemic criteria for knowledge evaluation. This dimension draws from science studies, particularly from the epistemology of science (Leach et al., 2003; Sandoval, 2005).
- Supporting the development of reasoning, particularly the choice of theories or positions based on rational criteria. This dimension draws from philosophy of science (Giere, 1988; Siegel, 1989, 1995, 2006) as well as from developmental psychology (Kuhn, 1991, 1993).

These contributions influence one another, although they are discussed separately, for the clarity of discussion. It has to be noted that by qualifying these contributions as potential we imply that their achievement is not necessarily warranted by the introduction of argumentation in the classroom. We acknowledge that the execution of these dimensions in the science classroom require a coordinated, complex and systematic set of pedagogical, curricular and assessment initiatives, among others. Table 1.1 summarises the dimensions and the perspectives or bodies of knowledge framing the dimensions.

Table 1.1 Contributions of argumentation and perspectives framing contributions

Potential contributions of argumentation	Drawing from
Making public and modelling cognitive processes	Situated cognition; communities of learners
Developing communicative competences, critical thinking	Theory of communicative action; sociocultural perspective
Achieving scientific literacy; talking and writing science	Language studies; social semiotics
Enculturation into scientific culture; developing epistemic criteria	Science studies; epistemology
Developing reasoning and rational criteria	Philosophy and developmental psychology

When pointing out the different fields or perspectives from which science education draws in promoting argumentation in the classroom, the implication is not that this is a one-way relationship. We believe that science education itself, through studies on argumentation, holds the potential to inform these perspectives in their disciplinary settings as well, leading to truly interdisciplinary investigations of argumentation. In other words, we contend that reciprocal contributions between these "feeding fields" and science education are desirable and fruitful in the production of knowledge in the field of argumentation studies.

Making Cognitive Processes Public: Argumentation and Situated Cognition

Constructivist perspectives view learning as a process of knowledge construction. A seminal piece of work supporting this claim was produced by Collins et al. (1989) who proposed to organise teaching as cognitive apprenticeship where knowledge and skills learning are integrated in their social and functional contexts. This proposal is related to Lave and Wenger's (1991) notion of situated learning, conceiving learning as increasing participation in a community of practice. Cognitive apprenticeship seeks to relate these knowledge and skills to their use in the real world. As Collins and colleagues point out, current pedagogical practices make invisible the key aspects of expertise, paying little or no attention to the processes through which experts acquire or use knowledge while performing complex or real tasks, for instance higher order processes. Applying the notion of apprenticeship to skills that are cognitive in nature requires internalisation of external processes. However in current educational contexts neither the teacher nor the students have access to the cognitive processes of each other, thus rendering impossible the observation or modelling of these processes. It may be noted that cognitive processes are made public through language and that natural language is both a tool and an obstacle for building scientific knowledge.

Brown and Palincsar (1989) base their proposal of guided cooperative learning in Vygotsky's (1978) notion of the social genesis of individual comprehension and in Toulmin's (1958) argumentation structure. These authors point to the role of collaboration in providing models of cognitive processes, as the thinking strategies are performed in public, modelling what then has to be performed privately. Argumentation in the context of classrooms where students are participants in a community of learners (Brown & Campione, 1990; Mason, 1996) may thus support the development of higher order cognitive processes (one of the goals for science education mentioned by Tiberghien, this book), given that reasoning becomes public and students are expected to explicitly back their statements with evidence and to evaluate alternative options or explanations.

Developing Communicative Competencies and Critical Thinking

Both critical theory and sociocultural perspectives view educational and mental processes in connection with their social and historical contexts. The critical theory conceived in the Frankfurt School can be described as a reflection on the relationships among social goals, means and values. For critical theory the goal of technical progress cannot be placed higher than democracy, and education is assigned a central role in social transformation. Carr and Kemmis (1986) contrast critical rationality and technical rationality, the latter being a perspective that views all problems as technical issues, depriving people from the capacity of controlling the world around them, with the consequence of diminishing the capacities of reflection and modification of situations by means of action.

For Jürgen Habermas (1981) critical theory is a form of self-reflective knowledge that expands the scope of autonomy, thus reducing domination. In his theory of communicative action Habermas distinguishes four types of social actions: (a) teleological, or goal oriented; (b) norms regulated (c) dramaturgical, or a performance in front of an audience constituted by the participants in the interaction; and (d) communicative, oriented to understanding one another in order to coordinate planned actions. Language and communicative competencies play a central role in communicative action: people reflect about themselves and about the world, and share these explanations with others. The theory of communicative action gives people pre-eminence over structures, assigning them the potentiality to develop actions directed to social change. As Kelly (2005) notes, in Habermas' framework, individual shifts to a social epistemic subject whilst reason is centred on communicative action and norms for argument are shared.

The perspectives of critical theorists contribute to a view of classrooms as places for communication. The acknowledgement of the importance of communication, of the relevance of language in knowledge construction, pointed out by Vygotsky (1978), is contributing to new lines of work in science education about the role of language in science learning, for instance in meaning making (Mortimer & Scott, 2003).

Given the theoretical precedence of the role of communication in education, it is essential to pay a closer look at the development of students' communicative competencies.

The need for promoting critical thinking has been advocated from different philosophical and psychological positions. From a philosophical perspective, Ennis (1992) defines critical thinking as reasonable reflective thinking focused on deciding what to believe in or do, and provides a set of criteria for assessing it. For Siegel (1992) a critical thinker refers to an educational ideal, and he emphasises the rationale for the assessment component of critical thinking and the disposition of critical thinkers to seek evidence for their beliefs. Understood as the search for evidence, critical thinking would be closely related to developing rational criteria, a position also maintained by some cognitive psychologists like Kuhn who explains the development of scientific reasoning as the coordination of theory and evidence (Kuhn, 1991; Garcia-Mila & Andersen, this book). But although critical thinking from the perspective of critical theory entails contrasting theories and beliefs with evidence, it also has a component related to the issue of emancipation. Furthermore critical thinking from this perspective is related to developing the capacity to criticise discourses which contribute to the reproduction of asymmetrical relations of power (Fairclough, 1995), or as Paulo Freire (1970) put it, to empowering students to understand the society around them and their own capacity to transform it. Teachers creating environments where students engage in argumentation about socio-scientific issues (see for instance Simonneaux, this book) include, among their goals, the development of critical thinking. Such critical thinking is related to the development of citizenship (Tiberghien, this book), of educating citizens that are critical thinkers, in the sense not only of a commitment to evidence, but also of an empowerment for critical rationality, the capacity to reflect on and influence social issues of relevance for their lives. Critical thinking can further be framed relative to scientific scepticism, as a tool for confronting pseudoscience and credulity.

Achieving Scientific Literacy: Talking and Writing Science

The recent focus on the role of spoken and written language in science learning seeks to redress an overemphasis on the recipe-like empirical (laboratory experiences) and rote mathematical (formulae) components of scientific knowledge in the classroom. Such change of focus cannot be seen as a return to rote-memory learning or use of textbooks as sole resources, in so far as it is rooted in a notion of the interpretative use of language and in the recognition of the importance of meaning construction (Mortimer & Scott, 2003). Norris and Phillips (2003) advocate the centrality of reading (interpreted as inferring meaning from text) and writing in learning science. In a similar vein, Yore et al. (2003) demand attention to the literacy component of science literacy, such as, for instance, critical reading of different sources, or participation in debates and argumentation among other modes of communication and communicative resources in the science classroom (Kress et al., 2001).

Lemke (1990) drew attention to the centrality of talk in science learning and to the need of promoting students' true dialogue or "talking science", a way of learning the language of science. Lemke's approach, grounded in the work of Mikhail Bakhtin (1986) who conceived communication as a social phenomenon, considers both scientific talking and scientific writing as social practices. The focus on discourse means an exploration of the features of texts that have rhetorical significance (Myers, 1990). Texts can be viewed as part of the social processes involved in the production of scientific knowledge, of the negotiations of the place and value of a claim in the structure of scientific knowledge given that science writing cannot be seen as reporting, but as construction of scientific facts (Myers, 1990). By engaging in argumentation students learn to talk and write the languages of science (see for instance Kelly et al., this book; Mason, 1998), including the rhetorical features (Kelly & Bazerman, 2003; Martins et al., 2001) such as persuasion in argumentation.

Enculturation in the Practices of Scientific Culture: Developing Epistemic Criteria

Learning science involves epistemic apprenticeship, the appropriation of practices associated with producing, communicating and evaluating knowledge (Kelly & Duschl, 2002). Kelly (2005) defines epistemic practices as the specific ways members of a community propose, justify, evaluate and legitimise knowledge claims within a disciplinary framework. With a focus on the science classroom, epistemic practices are defined by Sandoval and Reiser (2004) as the cognitive and discursive practices involved in making and evaluating knowledge, practices related to students' development of epistemological understanding. This epistemological understanding is viewed by Garcia-Mila and Andersen (this book) as cognitive foundation for argumentation. Leach and colleagues (2003) proposed teaching interventions aimed to foster epistemic understanding. Their studies are set in the context of an agenda exploring epistemic goals and practices, of a shift of focus on processes rather than on end products of science learning.

The appropriation by students of practices of the scientific community or the enculturation in the scientific culture is related to students' understanding of scientific epistemology—what in the literature is known as *personal* epistemologies. Kelly (2005) points to the social nature of the science epistemology, as epistemic criteria for justifying and evaluating knowledge are developed as social norms in a given community. Fostering students' appropriation of the epistemic practices of the scientific community is related to the goal of developing students' knowledge and skills about the nature of science proposed by Tiberghien (this book). Sandoval (2005) distinguishes among students' formal and practical epistemologies, the former being beliefs about professional science, the latter about their own practices with inquiry. Sandoval highlights an important reason for promoting the development of sophisticated epistemologies: the effective participation in policy decisions and the interpretation of scientific claims relevant for their lives, claiming that such outcomes are crucial for democracy. We see this dimension of epistemic understanding associated with the meaning of critical thinking discussed earlier. Argumentation, with its emphasis on justification of claims and on the coordination among claims and evidence, may support the development of epistemic criteria and more generally the enculturation in the practices of the scientific community. The relationships among argumentation and epistemology are discussed in detail in Sandoval and Millwood, and the development of epistemic criteria in Duschl (both chapters in this book).

Developing Reasoning and Rational Criteria

In a way, it could be argued that the development of the capacity of choosing among theories or positions is part of the development of epistemic criteria discussed in the previous section. For some authors, as already mentioned, rationality and critical thinking are treated as being almost synonymous. However, the ongoing controversy in science education as well as in philosophy of science (sometimes referred to as "science wars") locates rationality, epistemology and radical constructivism, among other issues as pivotal in relation to science learning. The "science wars" debate, as Peters (2006) puts it in his editorial for the special issue on philosophy of science education in *Educational Philosophy and Theory*, has been silenced in many occasions or publicised by means of a biased account, as in the Sokal affair. Incidentally, it may be noted that as the Hwang case sadly proves, scientific journals (*Science*, no less), and not only social studies journals, can be successfully hoodwinked into publishing forgery. Although these debates exceed the scope of this chapter, we consider the concept of rationality relevant for our purposes particularly in relation to science education and argumentation.

First, it has to be noted that issues surrounding rationality are complex issues, where different perspectives can be seen in a continuum, rather than in extreme black or white irreconcilable sides. We (the authors of this chapter) contemplate science both as a rational enterprise *and* as a social construction. There is no denying that scientific research is influenced by ideology, power or commercial interests. For instance, the issue of gender is tightly related to critiques of science, particularly given that perspectives of women and other marginalised sectors are conventionally underrepresented. But, as the feminist Sandra Harding (1991) argues, recognising sociological or cultural relativism does not entail epistemological relativism but rather a search for the most objective knowledge claims. In other words "A feminist standpoint epistemology requires strengthened standards of objectivity" (p. 142) leading to less distorted beliefs in natural phenomena.

If we agree that science is, or ideally should be, a rational enterprise then how can we define its rationality? For Siegel (1989, 2006) literature fails to distinguish three different questions about rationality. According to Siegel the central question is: What counts as evidence for some scientific hypothesis or procedure? In other words, Siegel sees rationality of science as being grounded in a commitment to evidence. On the other hand Siegel conceives of critical thinking as the educational cognate of rationality, involving consistency, impartiality and fairness. Siegel's perspective on rationality has not gone unnoticed nor uncriticised. For instance, Finocchiaro (2005) criticises Siegel's identification of critical thinking as rationality, proposing instead the notion of reasoning aimed at interpretation, evaluation or self-reflective presentation of arguments (critical reasoning) or methodological reflection. As discussed above, our own perspective is grounded on rationality as commitment to evidence whilst at the same time-sharing some of the tenets of the critical theory. In particular, we contend that critical theories enrich Siegel or Finocchiaro definitions by including the reflection about social environment and the potential to transform society. In terms of a philosophical referent, the resulting perspective could be rooted in the idea about the unfinished project of modernity (Habermas, 1997, 1981). For Habermas the modernity project, formulated by the Enlightenment, is based on rationality and its lack of vigour means, not that the Enlightenment goals should be discarded, but that they have not be achieved.

In summary, it can be said that the epistemic criteria developed to choose among theories or positions are rational criteria and their development may be supported by argumentation. In Fig. 1.1 we summarise some potential contributions of argumentation to the goals of science education implied by our discussion so far.

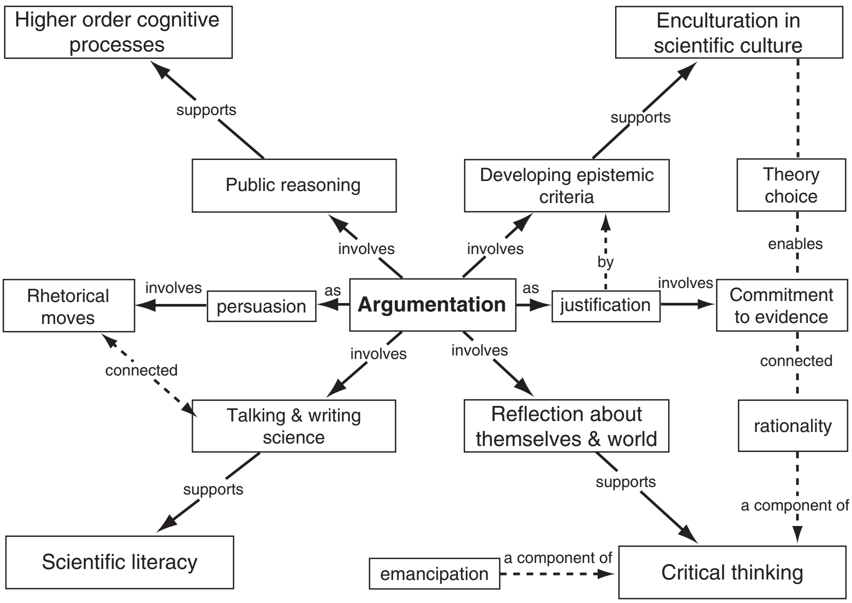

Fig. 1.1 Potential contributions from argumentation

Science education is conventionally seen as addressing goals of two sorts, which can be summarised as “science for all” and “science for prospective scientists”. Our position is that argumentation can contribute to both goals. More particular goals of contributing to the development of higher order cognitive processes, enculturation into scientific practices and epistemological understanding are also represented in the figure.

From the discussion so far some may be tempted to conclude that argumentation is a solution to most science education problems. This is not an implication that we wish to project. Rather we conceive of argumentation, on the one hand as a solution for some learning problems, to the extent that it helps students learn things that are hard to learn except through argumentation (e.g., evaluating evidence) and on the other hand as holding the potential to help us better understand and support the learning processes in the science classroom.

Meanings of Argument

For the purposes of this book it is important to clarify what we mean by argument. Is argument a statement or a process? Does an argument need to be produced by an individual or can it be co-constructed across individuals? Is argument always related to a dialogical context or can it take place internally in individuals’ minds? With respect to the last question, we agree with Billig (1987) who, in discussing the Greek philosopher Protagoras’ position on argument, points out that *argument* has both an individual and a social meaning: “The individual meaning refers to any piece of reasoned discourse. As one articulates a point of view, one can be said to be developing an argument” (p. 44). The social meaning is that of a dispute or debate between people opposing each other with contrasting sides to an issue. In other words, an argument can be either an inner chain of reasoning or a difference of positions between people and, as Kuhn (1993) notes, there is a link between the two. Social argumentation is a powerful vehicle for developing the higher order thinking that we call internal argumentation. In other words, social dialogue offers a way to externalise internal thinking strategies embedded in argumentation.

Not all authors would agree with this double meaning as, for instance, van Eemeren and Grootendorst (2004) restrict the meaning of an argument to the social one: “Argumentation is a verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint” (van Eemeren & Grootendorst, 2004, p. 1). For Plantin (personal communication) this definition, while apparently emphasising social aspects, adopts an entirely individual perspective. Perhaps both positions can be partly reconciled if, as Kuhn and Udell (2003) propose, we use the terms *argument* for the product, statement or piece of reasoned discourse and *argumentation* or argumentative discourse for the social process or activity, discussed in more detail in Garcia-Mila and Andersen (in this book). About the individual versus co-constructed production, we consider that both cases are possible, as illustrated in some empirical studies in other chapters.

From the different meanings of argumentation, at least two that are combined in van Eemeren and Grootendorst definition, are relevant for the science classroom context: argumentation as knowledge justification and argumentation as persuasion. We see this distinction related to two types of text construction discussed by Myers (1990, p. 103): scientific arguments, referenced in evidence, and narratives that function by persuasion. In science, knowledge construction is linked to knowledge justification, and claims should be related either to a path of logical clauses or to data and evidence from different sources (or to both). Hence, argumentation in scientific topics can be defined as the connection between claims and data through justifications or the evaluation of knowledge claims in light of evidence, either empirical or theoretical. Scientific claims are thus differentiated from opinions. Driver et al. (2000), Duschl and Osborne (2002) and Kuhn (1992), among others, suggest that science education should promote argumentation as one of the dimensions of learning science, and of the enculturation in the scientific discourse. Garcia-Mila and Andersen (this book) claim a broader relevance for argumentation, viewing it as a process aimed at the rational resolution of questions and involved in general knowledge acquisition. Other authors from philosophy have defined argumentation mainly in reference to justification. For instance according to Finocchiaro (2005) an argument is “an instance of reasoning that attempts to justify a conclusion by supporting it with reasons or defending it from objections” (p. 15).

Argumentation as persuasion can be defined as the process of convincing an audience (van Eemeren & Grootendorst, 2004). Acknowledgement of the role of discursive practices in the construction of scientific knowledge suggests that discourse has to be considered as being relevant for the appropriation of scientific culture by students. For Driver et al. (2000) the interpretation of argumentation as discursive practice is involved in the process of reaching agreement on acceptable claims or courses of action. Acknowledging the role of discourse does not mean that it is not possible to develop criteria for evaluating knowledge claims. We agree with Siegel (1989) and Driver et al. (2000) that argumentation is a rational process that relies on the rigorous application of knowledge evaluation criteria.

Our review of the meaning of argumentation will benefit from an historical overview of argumentation studies, as for instance, presented by Plantin (1996, 2005). For Plantin a turning point in these studies was the publication in 1958, of seminal work by Toulmin (1958) as well as Perelman and Olbrechts-Tyteca. On the focus on argumentation by these books, Plantin concurs, was a move towards legitimisation of a field discredited because of its association with rhetoric. Plantin sees the discredit of rhetoric in France at the end of the nineteenth century as being related to the prevalence of positivist views. The historical method was considered to yield legitimate knowledge whereas rhetoric, conceived as persuasion and even associated with trickery with words, was deemed not scientific, leading to the disappearance of the teaching of rhetoric from the French universities. After the Second World War, the ideological context changed. The emergence of argumentation studies can be interpreted as a reflection of the increasing attention at rationality of discourse as well as an attempt to promote "the construction of a democratic rational discourse, rejecting totalitarian Nazi or Stalinist discourses" (Plantin, 2005, p. 15; our translation). The life story of Chaïm Perelman (a scholar of Jewish origin) who contributed to the defence of Belgian Jews during the war, lends further support to the influence of the post-war context for the importance of rhetoric and rationality.

Perelman and Olbrechts-Tyteca (1958) subtitle their book as "the new rhetoric," and define argumentation theory as the study of discursive techniques that allow for the trigger or increase of adherences to proposed theses. The rationale they construct has the purpose of achieving value judgements, and consists of discursive techniques or tools that enable the justification of decisions or choices. Perelman and Olbrechts-Tyteca distinguish persuasive from convincing argumentation, the former being addressed to a particular audience whereas the latter addresses any rational being and is universal in nature. It has to be noted that there is a long tradition of argumentation and rhetoric studies in French exemplified by the seventeenth-century work *Logic or the Art of Thinking* (Arnauld & Nicole, 1992), also known as the *Port-Royal Logic*, work that Finnocchiaro (2005) regards as a precursor of argumentation and informal logic studies. Arnauld and Nicole treatise deals with issues such as the relationship between truth and intelligibility, or the principles of reasoning relevant to the discovery and justification of contingent truths. More recently, in the last decades of the twentieth century, several interesting studies on argumentation were produced in France derived from the field of language sciences. For instance, Anscombre and Ducrot (1983) emphasise the role of language in argumentation whilst Grize (1982) focuses on cognitive processes, providing a framework that is used by several French science education researchers (Buty & Plantin, in press). Unfortunately, there is paucity of English translations of the seminal historical texts as well as of the educational research in argumentation. One example of argumentation analysis using Grize's ideas is the work of Simonneaux (this book).

The argumentation model or scheme of Stephen Toulmin (1958) can be seen as a move towards the study of argumentation as it is practised in the natural languages, and therefore away from the schemes of formal logic. Insofar as the relationships between formal logic and logic in the natural discourse are concerned, we agree with Hintikka (1999) that formal logic remains inadequate for inferences leading to new discoveries: "the truths of formal logic are mere tautologies or analytical truths without substantial content and hence incapable of sustaining any inferences leading to new and even surprising discoveries" (p. 25). For Díaz and Jiménez-Aleixandre (2000) the implication is that while it could be used to represent or analyse *established knowledge*, formal logic is not an adequate framework to interpret discourse in situations where *new knowledge* is being generated. In situations consisting of natural discourse, for instance when solving a problem in the science classroom or laboratory, many propositions could be not correct or even fallacious from the perspective of formal logic, while at the same time constituting fruitful steps in the construction of knowledge. Toulmin himself sought to describe argumentation in practice and thereby challenge the notion of deductive validity.

He made a distinction between idealised notions of arguments as employed in mathematics and the practice of arguments in linguistic contexts, which, for him, should have close ties with epistemology. Toulmin was committed to a procedural interpretation of argumentation form as opposed to the rigid idea that all arguments have the form of “premises to conclusions”. Any justification of a statement or set of statements is, for Toulmin, an argument to support a stated claim. In other words, he places the validity of an argument in the coherence of its justification. In Toulmin’s model of argument, sometimes referred to as Toulmin’s Argument Pattern or TAP, an argument needs to make appeals to data, warrants, backings and qualifiers. Such appeals are context dependent. (For applications of Toulmin’s work in the analysis of classroom data on argumentation, see Erduran in this book).

Examining the form of arguments from different fields (e.g., law, science and politics), Toulmin was able to discern that some elements of arguments are the same while others differ across fields of inquiry. Toulmin termed the elements of arguments that are similar across fields as being field-invariant features of arguments whereas those elements that differed were called field-dependent features. Data, claims, warrants, backings, rebuttals and qualifiers are field-invariant, while “what counts” as data, warrant or backing are field-dependent. Thus, appeals to justify claims used to craft historical explanations would not necessarily be the same kind of appeals used to support claims for causal or statistical-probabilistic explanations. The flexibility of Toulmin’s model to function in both field-dependent and field-invariant contexts provides an advantage for understanding and evaluating the arguments posed by students in science.

Toulmin’s work has received much criticism. Plantin (2005), for instance, argues that Toulmin’s scheme is a model of rationale discourse adequate primarily for a monologue, although he appreciates the inclusion of the modal qualifier that can be conceived as the introduction of an element of dialogue. In science education some authors (e.g., Duschl, this book) have pointed to the inadequacies of TAP to account for dialogic argumentation, proposing instead the use of other models such as Walton’s (1996) as being more appropriate for the study of classroom discourse.

Walton (1996) frames his dialectical approach to argumentation in informal logic. For Walton (1989) in order to analyse argumentative discourse on controversial issues in natural language a number of questions must be taken into account, as for instance careful attention to language or the ability to deal with vagueness and ambiguity, and the researcher must be prepared to unravel the main line of argument from long exchanges among two or more people. Walton points out that in this dialectical approach the question–answer context of an argument is brought forward and an argument is seen as a part of an interactive dialogue of two (or sometimes more) people reasoning together. Walton’s (1996) argumentation schemes for presumptive reasoning are grounded on presumption as a practical notion that is used to enable a dialogue or an action to go ahead on a provisional basis. So it may be that not all the evidence that would be needed to reach a definite claim or option (or course of action) is available. Walton also offers an interesting distinction about explicit and implicit commitments of participants in a dialogue. He sees the commitment set of each participant as divided in two sides:

> a *light side*, a set of propositions known, or in view, to all the participants, and a *dark side*, a set of propositions not known to, or visible to, some or all of the participants. This dark side represents the implicit commitments. (Walton's emphasis, Walton, 1996, p. 26)

This distinction has been used by Jiménez-Aleixandre, Agraso and Eirexas (2004) in their analysis of students' arguments about an oil spill. Walton's typology of argumentation schemes can be interpreted also as a typology of justifications or warrants, or as a typology of appeals.

International Policies, Science Curricula and Argumentation

Apart from academic rationales for the promotion of argumentation in science education, there are policy level indications that argumentation as a skill is important worldwide. Computing technologies and trends in globalisation have contributed to a renewed vision that citizens across the world need to deal with a vast set of information and be able to evaluate such information. A significant aspect of such skills is the ability to argue with evidence. Internationally the phrasing of the national science curricula has begun to incorporate more of an emphasis on the need to teach students the skills of interpreting, evaluating and debating information. In addition, international comparative studies such as the Third International Mathematics and Science Study (TIMSS) have offered a rationale and support for reform needed in many countries. Likewise, the Programme for International Student Assessment (PISA) has been a driving force in the advancement of skills such as the ability to coordinate evidence and claims. PISA is an internationally standardised assessment that was jointly developed by participating countries and administered to 15-year-olds in schools. The survey was implemented in 43 countries in the first assessment in 2000, in 41 countries in the second assessment in 2003, in 57 countries in the third assessment in 2006 and 62 countries have signed up to participate in the fourth assessment in 2009. Tests are typically administered to between 4,500 and 10,000 students in each country.

The PISA Assessment Framework, although does not mention argumentation as a term, explicitly emphasises the role of evidence in the reaching of conclusions:

> An important life skill for young people is the capacity to draw appropriate and guarded conclusions from evidence and information given to them, to criticize claims made by others on the basis of the evidence put forward, and to distinguish opinion from evidence-based statements. Science has a particular part to play here since it is concerned with rationality in testing ideas and theories against evidence from the world around. (OECD, 2003, p. 132)

Furthermore, there is emphasis on the role of knowing and applying of processes to select and evaluate information and data (p. 133). Indeed the very definition of scientific literacy is framed in terms of evidence-based conclusions (p. 137).

Scientific literacy is envisaged as involving three main processes: (a) describing, explaining and predicting scientific phenomena; (b) understanding scientific investigation; (c) interpreting scientific evidence and conclusions. An example assessment framework incorporating the third strand is given in Appendix A.

Across the world, there is an increasing trend to incorporate ideas about how scientific knowledge construction occurs and how argument can contribute to the process of scientific knowledge construction. In the United States, American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) have been strong advocates and supporters of reform (AAAS, 1993; NRC, 1996). For example, the "Science as Inquiry Standard" emphasises the importance of students' understanding of *how* we know what we know in science. In the United Kingdom, the importance of argument, the justification of claims with evidence, is recognised as an educational goal through the *Ideas and Evidence* (DfES/QCA, 2004) and *How Science Works* (QCA, 2007) components of the National Science Curriculum. The basic position underlying these components of the curriculum is that students should leave schooling with a deeper sense of the nature of scientific knowledge—how ideas are produced, evaluated and revised in science. In upper secondary schooling at Key Stage 4, the Qualifications and Curriculum Authority states that:

> "How science works" focuses on the evidence to support or refute these ideas and theories. The evidence comes from the collection and creative interpretation of data, both of which need to be considered. Consequently, in order to understand how science works, learners need skills such as practical collection of data, working safely, presenting scientific information; they need to understand the power of science to explain phenomena, the way understanding of science changes over time and the applications of contemporary scientific developments. (QCA, 2007)

In the new Spanish National Curriculum for secondary schooling the relevance of the use of evidence and of argumentation is emphasised both in the general definition of basic competencies and in the description of goals in the science subjects. For instance the basic "Competency about knowledge and interaction with the physical world" states that:

> This competency ... enables to engage in rational argumentation about the consequences of one or another way of life, and to adopt a stance towards a healthy life both physically and mentally (...) This competency makes possible to identify questions or problems and to draw conclusions based on evidence, with the goal of understanding and making decisions about the physical world and about the changes produced by human activity in the environment, the health and people's quality of life. (MEC, 2007, p. 687; our translation)

The description of the contributions of science to the basic competencies also highlights "a particular way of constructing discourse, aimed at argumentation" (MEC, 2007, p. 692) and includes the skill of argumentation among the general objectives of science education for compulsory secondary school, from 12 to 16 years.

In the secondary science curriculum in South Africa, one of the learning outcomes focuses on the nature of science and its relationships to technology, society and environment. Here the expectation is that: