Chapter 5
Designing Argumentation Learning Environments

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Teacher:	*Look, now there is a person, Moncho* (researcher) *who is studying this classroom, right? Well: Could he do it if he took any of us out of the classroom?*
Pupils:	*No, no*
Teacher:	*What does he want? He wants to study the whole class… with children, walls, tables, what is performed…. The same happens with the pond… looking only to a newt, waiting for it to grow, to mate… it would be impossible to get an idea of the pond.*

How can we support pupils' engagement in argumentation? Should argumentation be explicitly taught or rather embedded in the learning tasks? Which design principles are related to the goal of promoting argumentation in the science classroom? Are they the same as design principles for constructivist learning environments? How can research explore these features of learning environments supporting argumentation?

The above excerpt (Jiménez-Aleixandre et al., 2005) comes from a 4th-grade classroom (9–10-year-olds), during the process of jointly planning a field trip by teacher and pupils, including decisions about topics to be studied and methods to study them. The teacher uses an analogy between ecology and classroom studies that is the reverse of another analogy found in educational papers (see for instance Doyle, 1977) that propose viewing the classroom as a complex system of relationships and interactions similar to the relationships in ecosystems. Here the presence of the researcher, Ramón López, in the classroom is used to exemplify both the need for an approach to the pond as a whole and of doing it in the field. Implicit in the teacher analogy between the classroom and the pond is the goal of promoting pupils' reflection about their own learning processes and about the ways of constructing knowledge concerning the pond.

The use of this analogy can be seen as connected to the third, fourth and fifth questions formulated in the first paragraph, the last concerning research about argumentation learning environments, a research tightly interwoven with the design principles aimed at promoting argumentation, the subject of the third and fourth questions. These design principles intend, among other goals, that pupils reflect about their own learning. The relationships among designing environments to promote argumentation and investigating them can be connected to the impact on some science educators, like myself, initiating

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research about argumentation at the beginning of the 1990s, of Brown's (1992) notion of design experiments, of studying learning "in the blooming, buzzing confusion" of classrooms. It is interesting to note that in this same year of 1992, during a postdoctoral study with Peter Hewson at the University of Wisconsin, I had been inside the 4th-grade class taught by Sister Gertrude Hennessey, where I witnessed a kind of design experiment: how children were encouraged to think aloud about physics problems and their own learning, and were even able to use the conceptual change language to talk about the intellectual status of their own ideas (4th-Grade Students, 1992; Hennessey, 1991). This is an indication that the methods used to study conceptual change (at least by some of the authors of this notion), and the learning goals pursued are part of a continuum with the classroom studies exploring argumentation and other epistemic practices.

It has to be acknowledged that, twenty-five years ago, Posner et al., (1982) proposed that the students were the ones who had to decide whether the conditions for conceptual change—that is the epistemic status or, in their own terms, the intellectual status, of their own ideas; whether they were or not intelligible, plausible, fruitful or unsatisfactory—were met. Although it may be said that the idea of conceptual change has been, in Toulmin's terms, ecologically successful, some of its proposals have been overlooked or distorted, for instance, as Hewson and Thorley (1989) pointed out, it is a distortion to consider that these conditions are met because the teacher judges it to be so from responses about scientific content. Pupils' reflection about their ideas and their learning is a relevant component of environments designed to promote epistemic practices, as argumentation. Hewson (1985) also drew attention toward the role of the students' epistemological commitments, or evaluative standards, in learning science, for if students are not committed to consistency, generalizability or the relevance of explanatory power, they would not feel the need for a change of status in their ideas. It can be noted that students' first commitment may be to criticize each other's inconsistencies or irrelevant remarks. Epistemological commitments are part of the development of epistemological understanding, crucial for argumentation (see Garcia-Mila & Andersen, this book).

This chapter discusses the features of learning environments that promote argumentation in science classrooms through a review of reported research. As it has been noted (Kuhn, 1992), although the development of argumentation skills is a desirable goal, most school environments do not favor it. In the first section theoretical perspectives framing research about learning in real-life contexts are outlined. In the second section, design principles related to the goal of promoting argumentation are discussed. Then the attention is turned to two types of contexts from which this chapter draws: in the third section to classrooms where argumentation has been explicitly taught, and in the fourth to classrooms where it has not been taught, but is embedded in the learning tasks and classroom climate. The chapter ends outlining some educational implications.

Social Constructivism as a Rationale for Classroom-Based Research on Argumentation

Learning argumentation and other epistemic practices makes part of the goals of constructivist science classrooms, and is grounded on social constructivist views of learning. Ann Brown (1992) suggested that one of the greatest challenges for educational research in the 1990s was the design, implementation and evaluation of teaching sequences and set, as a high-level goal, building communities of learners in the classroom (Brown & Campione, 1990), in which students take charge of their own learning. She called these classroom studies aimed to engineer learning innovations "design experiments". For Brown this was a way to reconcile the tensions between two goals, contributing to a theory of learning and to practice. Such approach emphasizes the connections among the curriculum designed, taught and learned, among educational research and educational innovation and contrasts with a long tradition of psychological research, and in general educational research, studying cognitive processes or educational questions in conditions as controlled as possible.

As Salomon (1993) noted, the study of complex phenomena under tightly controlled conditions assumes that the phenomenon is the same in these conditions and in real-life circumstances, treating cognition as possessed and residing in the heads of individuals, while the examination of people in real-life problem-solving situations suggests that they "appear *to think in conjunction or partnership* with others and with the help of culturally provided tools and implements" (Salomon, 1993, p. xiii; italics in the original). For Brown (1992) classroom life is synergistic and it is difficult to study any one aspect independently from the whole system. This does not mean that laboratory studies have little value, but rather than laboratory and classroom-based studies have different objectives and complement each other. Brown brilliantly deconstructed one of the criticisms challenging the validity of intervention studies, the Hawthorne effect, or the fact that any intervention may have a positive effect merely because of the attention of the researchers to the participants. Revising the original study, Brown found that one of the conditions for improvements to occur was that workers perceived that they were in control of the conditions of their work, arguing that this perception of control, or real control, was what she intended in the classroom, with pupils taking charge of their own learning, an issue that will be traced in the next section.

The relevance accorded to control by the students of their own learning and thinking is consistent with cognitive psychology approaches (see Garcia-Mila & Andersen, this book) that, on the one hand, see evaluative thinking as the higher category in epistemological understanding, the level in which claims (products of knowing) can be evaluated according to whether they are more or less supported by evidence (Kuhn, 2005); and on the other, conceive advanced forms of thinking as the capacity to evaluate thinking "with respect to how well it serves the purposes of the thinker" (Moshman, 1998, p. 953). For Moshman this advanced form of thinking is reasoning, defined as the deliberate application of epistemic constraints to one's own thinking.

Classrooms conceived as communities of learners or intentional learning environments (both names are used by Brown and colleagues) draw from the situated cognition approach. Brown et al. (1993) explicitly link their proposal to Bourdieu's (1972) notion of communities of practice and to Lave and Wenger (1991) perspective of learning as increasing participation in communities of practice, situated in a certain activity, context and culture. Lave and Wenger's approach highlights, rather than the cognitive processes involved, the kind of social engagements that provide the proper context for learning to take place. This emphasis on social interaction as an essential component of both cognitive development and learning is rooted in the work of the Russian cultural-historical theorists, Vygotsty, Luria and Leont'ev. Many social processes related to psychological functions are communicative, and Wertsch (1991), weaving together Vygotsky's and Bakhtin's notions, points out that both authors coincide in the idea that communicative human practices give origin to the psychological functions of individuals. To Vygotsky (1978) and Luria we owe also the idea of mediation, conceiving human action as mediated by tools and signs: higher mental processes have its origin in activities socially mediated.

The distributed cognitions approach draws from this school of thought and expands some of its notions, as the activity systems, including their collective dimension (Cole & Engeström, 1993) alongside with tools (both physical and symbolic), subject and object. The role of social interaction in the development of higher thinking skills and the collective dimension of activity systems are relevant both for the design of learning environments to support argumentation and for the research about them, for argumentation is viewed as a social process or activity. Distributed intelligence is seen by Pea (1993) rather as a heuristic framework for raising and addressing theoretical and empirical questions about mind, culture, symbol systems and human thought, that a theory. For Pea, the consideration of knowledge as socially constructed has to be extended to the interaction among thinking and artefacts, so intelligence may also be distributed for use in designed artefacts as physical tools, representations or computers.

A development of Vygotsky and Bakhtin notions of words as tools for thinking and communication as a social phenomenon, into an instrument for research and classroom planning, is Mortimer and Scott's (2003) work about communicative approaches in the classroom, with the aim of exploring the links between classroom talk, meaning construction and learning. Mortimer and Scott see meaning making and understanding as dialogic processes. The meaning of *dialogic*, based on Bakhtin, is that attention is paid to more than one point of view, to more than one "voice": the teacher explanation can be dialogic if she or he refers to students' ideas, irrespective of being uttered by only one person. The personal process of meaning making is also viewed as a dialogue, for instance between old and new ideas or voices, played in the individual's mind. These authors borrow from Sutton (1992) the notion of the development of the scientific story as a persuasive process leading to the constitution of a thinking community. Mortimer and Scott's analytical frame to plan and study teaching sequences proposes to think about science teaching and learning in terms of the social language of school science, of the Bakhtinian idea of speech genre (Bakhtin, 1986), or distinctive patterns of language used in specific contexts, distinguishing between the multifarious genres of everyday language and the multifarious speech genres of school science, characterized by rhetorical devices such as asking questions or repeating statements. The students must not only recognize them, but also learn how to participate using them. These notions are relevant for studying and supporting argumentation, which, understood as knowledge evaluation, involves dialogic activity and can also be viewed as persuasion; on the other hand, if argumentation is part of the speech genres of science, it should be part of the speech genres of school science.

It may be said that, since the beginning of the 1990s, a substantial part of science education research has shifted from surveys towards the study of classroom discourse, of students' and teacher's talk, of the processes—sometimes slow and painful—of negotiation, reasoning, meaning making. The role of language and communication (either spoken or written) in the classroom, and in the construction of scientific knowledge, has been recognized. As discussed in Jiménez-Aleixandre and Erduran (this book) teaching organized as cognitive apprenticeship requires making cognitive processes public, something that could be supported by argumentative practices, where students are required to publicly justify their knowledge claims. From this outline of some approaches framing research about argumentation, I will now turn to the design principles informing its introduction in the science classroom.

Design Principles for Appropriating the Practice of Argumentation

Design principles are guidelines expressing the goals for the learning outcomes, the classroom activities and the teaching strategies. It is important to clarify how are the design principles aimed at supporting argumentation related to the design principles and goals for constructivist learning environments. Learning the practice of argumentation in science classrooms cannot be viewed as an objective disconnected from learning science, on the contrary, it makes part of the goals of constructivist science classrooms, where the roles of students are to be knowledge producers (Jiménez-Aleixandre & Pereiro, 2002), teachers, mentors (Brown et al., 1993); the roles of teachers are to scaffold their progressive assumption of responsibility (Reigosa & Jiménez-Aleixandre, 2007), to model and guide inquiry; and the criteria for assessment are publicly shared (Duschl, this book). So, if learning environments designed to support argumentation can be described as a type of constructivist learning environments, the question is which features in them are specific for argumentation purposes. In this chapter it is claimed that these features are related to the development of epistemic practices (Sandoval & Reiser, 2004), and in particular to the *evaluation of knowledge*.

In this section the underlying design principles of classrooms seeking to promote argumentation, in connection with constructivist classrooms, are outlined around six main issues: role of students, role of teacher, curriculum, assessment, metacognition and communication approach, all revolving around knowledge evaluation. The issues, illustrated with instances from argumentation studies, are not independent, but forming part of a systemic whole (Brown, 1992). These six

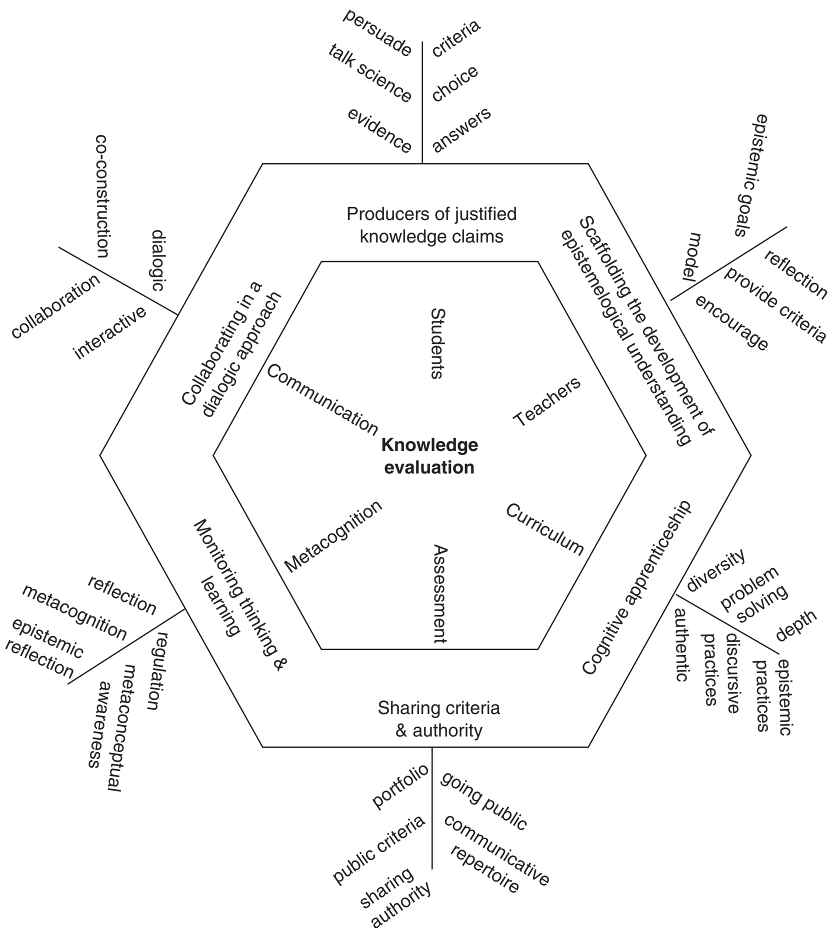

Fig. 5.1 The argumentation snowflake. Summary of design principles

design principles are represented in Fig. 5.1 in the argumentation "snowflake". Why a snowflake? Not only because it possesses hexagonal symmetry, but also because it is beautiful, as elegant arguments should be, and grows around a first particle of ice at its center, here occupied by knowledge evaluation.

Active Producers of Justified Knowledge Claims: The Role of Students

Constructivist classrooms are centered on the students who, in them, have to develop control of their own learning, acting as knowledge producers rather than as consumers of knowledge produced by others. Being in control is central for promoting argumentation and it is connected to an environment that requires from the students the performance of epistemic practices, defined by Kelly (2005) as proposing, justifying and evaluating (we may add criticizing) knowledge claims. According to Resnick (1989) the use of strategies to construct new knowledge depends on whether or not people view themselves as being in charge of their learning. This can be framed in the notion of *intentional learning* (Bereiter & Scardamalia, 1989), learning actively desired and controlled by the learner. Bereiter and Scardamalia suggest that "the skills a student will acquire in an instructional interaction are those required by the student's role in the joint cognitive process" (op cit p. 383). In the case of argumentation, it would mean that for the students to develop argumentative competencies, like justifying a claim or evaluating claims made by others, these competencies should be required for their role in the classroom. The implication would be that learning environments designed to promote argumentation should engage students in knowledge evaluation practices. In argumentative contexts students are required, among others, to perform several or all of the following:

To *generate products or answers*, in the form of proposals, claims, solutions, experimental designs, or artifacts, for questions and problems (e.g., Baker, 2002; Ergazaki & Zogza, 2005; Jiménez-Aleixandre & Pereiro, 2002; Kelly et al., 1998; Kolstø & Mestad, 2005).

To *choose* among two or more *competing explanations* or theories (e.g., Kenyon et al., 2006; Osborne et al., 2004a) about a phenomenon; or among several alternatives or courses of action (e.g., Kortland, 1996; Patronis et al., 1999; Ratcliffe, 1996; Schweizer & Kelly, 2005; Zohar & Nemet, 2002), alternatives that could have been generated by themselves.

To back their claims or choices with *evidence* (e.g., Osborne et al., 2004a; Sandoval & Reiser, 2004), which may adopt various forms: to select data, empirical or hypothetical, appropriate for supporting their claims (e.g., Jiménez-Aleixandre et al., 1999; Mortimer & Scott, 2003); to examine experimental evidence in the light of previous prediction (e.g., Mason, 1996); to draw on their knowledge in order to generate justifications and to articulate reasons for supporting a claim (e.g., Kelly & Takao, 2002; Sandoval & Millwood, this book).

To develop knowledge evaluation competencies, to use *criteria* to distinguish good from poor arguments (e.g., Jiménez-Aleixandre et al., 2004; Osborne et al., 2004a; Zohar & Nemet, 2002); to evaluate the significance of pieces of evidence (e.g., Hogan & Maglienti, 2001; Kenyon et al., 2006); to share standards for argued points of view (Kortland, 1996, 2001).

To *talk science* and *write science*: to discuss the design of their pathways to solve experimental problems (e.g., Jiménez-Aleixandre & Reigosa, 2006; Kelly et al., 1998); to formulate hypotheses and design experiments to test them (Ergazaki & Zogza, 2005; Kolstø & Mestad, 2005); to agree upon group reports (e.g., Patronis et al., 1999); to produce research papers (see Kelly et al., this book).

To attempt to *persuade* others or to reach an agreement with their peers, for instance about socio-scientific issues as the contribution of humans to global warming (Schweizer & Kelly, 2005), the production of transgenic fishes (Simonneaux, this book), or the management of wolfs (Mork, 2005), or about ecological relationships (Kuhn & Reiser, 2007), or about their own behavior towards wildlife in a field trip (Jiménez-Aleixandre et al., 2005).

These roles of students are related: they generate products, choose among them, back their choices with evidence, use criteria to evaluate the significance of the evidence and report the process. As a summary, in argumentative contexts, students are active producers of justified knowledge claims and efficient critics of others' claims.

Scaffolding the Development of Epistemological Understanding: the Role of Teachers

Constructivist teaching and learning place the students at the center of instruction, but this does not mean that in a classroom conceived as a community of learners the teacher has the same role as the students (Brown et al., 1993), on the contrary, the teacher directs research and steers the learning goals. He or she has authority (Mortimer & Scott, 2003), which does not mean an authoritarian stance, for these perspectives are explicitly anti-authoritarian, but being responsible for justifying why inadequate options are inadequate. Learning is viewed as a process of social participation (Lave & Wenger, 1991), which requires modeling and coaching. In Vygotsky's terms the teacher is the more able peer, providing scaffold for the students' performances and promoting their assumption of responsibility (Reigosa & Jiménez-Aleixandre, 2007). Tasks and responsibilities are distributed among the participants in the community (Cole & Engeström, 1993). In argumentative environments the teachers take on roles as, for instance, the following:

To *model* and guide *inquiry* for, as discussed below about curriculum, inquiry and argumentation goals are complementary, and inquiry contexts provide appropriate environments for argumentation to take place. For Brown et al. (1993) the teacher models scientific inquiry so "Children witness teachers learning, discovering, doing research, reading, writing, and using computers as tools for learning, rather than lecturing, managing, assigning work, and controlling the classroom exclusively" (Brown et al. 1993, p. 207).

To *encourage students to provide evidence* to justify a position (e.g., Simon et al., 2006); to ask open questions aimed at eliciting justifications (e.g., Jiménez-Aleixandre et al., 2005; Simon et al. 2006), such as "Why do you think that?" "How do we know it?"; to challenge ideas pointing out its limitations or inconsistencies (e.g., Mason, 1996; Mork, 2005).

To develop and *provide criteria* for the construction and evaluation of arguments and argument components, either as prompts (Osborne et al., 2004a) or as a written rubric (Sandoval & Reiser, 2004). Some instances of criteria are: for arguments, good arguments include true, reliable and multiple justifications, refer to alternative arguments and rebut them (Zohar & Nemet, 2002); for evidence, appropriate evidence is specific and came from data not from opinion (Kenyon et al., 2006).

To translate *epistemic goals* related to argumentation into their oral contributions. Some instances of argumentation processes reflected in teacher utterances coded by Simon et al. (2006) are: talking and listening; knowing meaning of argument; constructing arguments; evaluating arguments or counterarguing and debating.

To encourage students' *reflection* about their positions, about changes in positions as a consequence of the teaching sequence or the debates, and about the reasons underlying that change (e.g., Jiménez-Aleixandre & Pereiro, 2005; Simon et al., 2006).

These roles are related: teachers model inquiry and, as part of it, encourage the use of evidence and students' reflection, and provide criteria for evidence. In summary, in classrooms promoting argumentation teachers have to scaffold the development of epistemological understanding. Zohar (this book) discusses how teachers can develop the capabilities related to teaching argumentation.

Inquiry and Argumentation Instruction as Cognitive Apprenticeship: The Curriculum

Kuhn (2005) places inquiry and argumentation at the center of a thinking curriculum. An inquiry perspective has consequences not only for the curriculum, but also for the roles of students and teachers. Sandoval and Reiser (2004) view inquiry instruction as a cognitive apprenticeship into scientific practice, pointing out that inquiry-based efforts "must emphasize that the processes scientists value for generating and validating knowledge emerge from epistemological commitments to what counts as scientific knowledge" (Sandoval & Reiser, p. 345). Some of the features of curriculum in argumentative contexts are discussed below.

The curriculum is organized around *authentic activities* (Brown et al., 1989), as in projects SEPIA (see Duschl, this book), or RODA (Jiménez-Aleixandre & Pereiro, 2002), dilemmas drawn from real life (Zohar & Nemet, 2002), because the students' performances in them would create an appropriate environment for argumentation, which in standard classrooms is not likely to occur. Authentic activities are these that constitute problems, not just rhetorical questions, for instance an unexpected obstacle encountered in a process of genetic engineering (Ergazaki & Zogza, 2005); that are relevant, or perceived as relevant for the lives of the students, as the controversial issue of wolfs in Norway (Mork, 2005) or cloning (Sadler & Zeidler, 2005); that require to be solved using inquiry procedures (Kolstø & Mestad, 2005; Kuhn & Reiser, 2007). Brown et al. (1993) discuss what should *authentic* and *inauthentic* mean in school science classrooms, pointing out that, to suggest, as Brown et al. (1989) do, enculturation of students in the cultures of science (mathematics, etc.) practitioners, is romantic, as teachers are not practitioners themselves. A. Brown et al. propose instead that schools should be communities where students learn to learn, teachers model intentional learning, and graduates of such communities would be people who have learned how to learn in many domains, who know how to go about gaining new knowledge. An interesting distinction is made by Sandoval and Reiser (2004), who propose a focus on engaging students in the reasoning and discursive practices of scientists, which does not necessarily mean the exact activities of professional scientists.

Curriculum structured as *problem solving* provides an environment for students to productively engage in investigations (e.g., Eichinger et al., 1991; Kelly et al., 1998) and apply their knowledge to solve the problem.

Tasks are designed in order to produce a *diversity of outcomes*, to involve considering a *plurality of explanations*. Diversity is grounded in a view of knowledge as socially constructed through challenges brought about by differences in perspective (Pea, 1993). This diversity supports the evaluation of alternatives and students' engagement in argumentation, for instance in projects SEPIA (Duschl, this book), RODA (Jiménez-Aleixandre & Pereiro, 2002, 2005) or IDEAS (Osborne et al., 2004).

Proposals, solutions or alternatives generated have, as a consequence of design, different *epistemic statuses* and these can undergo modifications along the process. Baker (2002) proposes five conditions for argumentative interactions to take place: a diversity of proposals (solutions, methods to obtain them); proposals or solutions distributed across interlocutors; proposals having, from the point of view of participants, different epistemic statuses, as for instance more or less plausible, true, believable, acceptable; the requirement, inherent to the instructional context, to choose between them; and finally, in order to resolve the problem of choice, "the interlocutors establish links between them and other proposals, called arguments and counterarguments, the creation of which potentially modify the epistemic statuses of the initial proposals" (Baker, 2002, pp. 306–307). Baker further proposes a second way in which the epistemic statuses of proposals can be modified, to transform their meaning using discursive operations, meaning negotiations.

Depth is preferred over breadth, recurrence over fragmentation (Brown, 1992; Brown et al., 1993). For instance in project SEPIA conceptual goals are kept to a *limited number* so as to facilitate the adoption of epistemic criteria to assess knowledge claims (Duschl, this book).

Resources are designed to *support the development of scientific epistemic practices*. A particular case is the use of Information and Communication Technologies (ICT) to support argumentation. Pea (1993) claims that the use of ICT has to be incorporated to the design principles of innovative classrooms, on the grounds that tools serve as artefacts of distributed intelligence, with affordances such as science visualization, or augmenting intelligence through external representational systems. Sandoval and Reiser (2004) discuss the ways in which Explanation Constructor, a software tool, supported students' inquiry and provided epistemic forms for students' expression of their thinking and for communicating evaluation criteria. For instance, students had to select specific pieces of data as evidence and link them to specific causal claims, so the distinction between claim and evidence is made both in the representations used and in the students' manipulation of those representations. A detailed discussion of the role of information technology in supporting argumentation is found in Clark et al. (this book).

In summary, the curriculum in argumentative contexts is structured as solving authentic problems, which generate a diversity of outcomes with different epistemic statuses, and uses resources that support epistemic practices. The goal is to engage students in inquiry, in the discursive practices of scientists.

Sharing of Criteria and of the Authority to Evaluate: Assessment

For Brown et al. (1993) maintaining standards of accountability while at the same time keeping the social contract with students, who are encouraged to view themselves as co-equals participants in a community is a difficult tightrope to walk. These authors' approach is to allow students to participate in the assessment process as much as possible. Two dimensions of evaluation have to be taken into account, the students' participation in the assessment of the instruction process and the sharing of criteria to evaluate knowledge. Some features of assessment in argumentative contexts are:

The participation of students in the assessment of the goals of the teaching sequences (e.g., López & Jiménez-Aleixandre, 2002) as they had participation in the decisions about the content to be studied, the methods of study and the norms related to it. López and Jiménez-Aleixandre characterize the teachers' performance in their study in this respect as *sharing* with the pupils the *authority to evaluate*.

Sharing of criteria for the assessment of students' products and performances, which in the SEPIA project is carried through a discourse strategy labelled "assessment conversation" (Duschl, this book). *Developing criteria* for evaluating claims (see e.g., Jiménez & Pereiro, 2002; Kenyon et al., 2006; Kortland, 1996).

Making *cognitive processes public*: Brown et al. (1993) discuss dynamic assessment methods grounded in the Vygotskian zone of proximal development, being one of its features the externalization of mental events via discussion formats. Making external processes that are carried out internally may support cognitive apprenticeship. In argumentative contexts students are required to make explicit the evidence for their claims (e.g., Mason, 1996).

The use of *portfolio* as a part of the assessment (e.g., Duschl, this book; Jiménez-Aleixandre & Pereiro, 2002) facilitates the students' reflection on their own learning, comparing their initial proposals, claims or justifications with their current ones.

The use of multiple ways for students to display their competence as science learners, to demonstrate knowledge, beyond taking written examinations. As Crawford (2005) argues, what counts as knowing is an interactional accomplishment among participants and, as her case study shows, a teacher can construct a learning environment in which multiple discourse practices are valued as knowing science. Some instances of this *communicative repertoire* are: explaining visual representations, taking the role of teacher, solving problems, explaining phenomena or questioning data.

As a summary, in argumentative contexts teachers and students share both the public criteria for assessment and the authority to evaluate through portfolio and different instances of a communicative repertoire.

Monitoring Thinking and Learning: Regulation, Reflection and Metacognition

A central claim in this chapter is that a specific feature of argumentation learning environments is the evaluation of knowledge claims, and therefore that their goals should include the development of epistemological understanding to the level of evaluative thinking. Knowledge evaluation practices are intentional and require a high degree of reflection about thinking. The monitoring by students of their own thinking and learning processes can occur at different stages, from reflection to metacognition and epistemic cognition (Kitchener, 1983).

Monitoring comprehension can be viewed as a basic competency for learning science. The process of noticing and fixing difficulties when reading science texts has been studied by Otero (2002; Otero & Campanario, 1990) who found that students have difficulties in detecting contradictions contained in a short paragraph. Some researchers distinguish two components in comprehension monitoring: evaluation, that is, noticing the comprehension problem, and *regulation*, or the process of repairing it. However, for Otero (2002) these two phases are not independent of each other. Although these studies are not related to argumentation, they point to the difficulties encountered in developing regulation processes in science education. Conceptual change is also related to regulation; in this case of the intellectual status of the learner's ideas, and some studies have examined the difficulties of students when confronted with anomalous data that contradict their theories (Chinn & Brewer, 1993).

Metacognition is thinking about thinking. According to Zohar (2004) it is used in two different senses: metacognitive knowledge, that is, what one knows about cognition, and metacognitive control processes, or the use of that knowledge to regulate cognition. Metacognition, strictu sensu, is documented only when students make explicit references to their thinking and knowing processes. Although sometimes students' references to their ideas are characterized as metacognitive, here a distinction is drawn among reflection upon one's learning and explicit awareness of the significance of thinking strategies. In argumentative environments these practices include for instance:

Students' *reflections* about the character of the knowledge that they have been asked to extend and apply in decision-making (Kortland, 2001); this reflection is built in the task.

Students' *metaconceptual awareness* of their ideas, for instance about their initial conceptions, the reasons for it and conceptual change (Mason, 1996); or about the differences among their positions at the beginning and the end of the teaching sequence and about the data influencing the change (Jiménez-Aleixandre & Pereiro, 2005; Mason, 1998).

Students' *metacognitive reflections* for instance about the argumentation standards (Zohar & Nemet, 2002); or about the advantages of learning by themselves in contrast with being told something (Jiménez-Aleixandre et al., 2005).

Students' *epistemic reflections* about the evaluation of scientific explanations, the causal coherence of their claims, their fit with available data (Sandoval & Reiser, 2004), in this study both tools and tasks create opportunities for this reflection.

As a summary, in argumentative environments students are engaged in reflection about their knowledge and their thinking and learning processes.

Collaborating in a Dialogic and Interactive Setting: The Communicative Approach

Talk and other modes of communication are a central dimension of science classrooms. Mortimer and Scott (2003) analytical framework for communicative approach locates classroom talk along two continua: interactive to non-interactive, depending on the participation of students; and dialogic to authoritative, depending on the attention paid to different points of view or voices (dialogic), or the absence of it (authoritative). These two dimensions can be found in all four combinations in science classrooms and, for Mortimer and Scott, in any teaching sequence there should be variation in communicative approach. Acknowledging this diversity, it seems that argumentation would be supported in contexts where *interactive* and *dialogic* approaches dominate over non-interactive or authoritative ones. Some features of these classrooms could be:

Collaborative learning, grounded in approaches viewing knowledge as socially constructed and cognition as distributed. It has at least two dimensions: designing and organising forms of collaboration, as reciprocal teaching or the jigsaw method, and establishing a community of discourse in a collaborative atmosphere, where discussion, questioning, evaluating, criticism are the mode rather than the exception (e.g., Brown et al., 1993; Mason, 1996). Collaborative discourse allows participants to negotiate meanings, explanations and standards for evidence (e.g., Kelly et al., 1998; Sandoval & Reiser, 2004).

Interactive contexts where argumentative interactions may take the form of attempts to convince, of negotiation of choices, or of cooperative explorations of a dialogical space of solutions (Baker, 2002). The discourse in a classroom which has as a goal promoting argumentation can be characterized as interactive and *dialogic* (Mork, 2005).

Cooperative efforts resulting in the *co-construction* of arguments (e.g., Jiménez-Aleixandre & Pereiro, 2005; Jiménez-Aleixandre et al., 2000; Mason, 1996) with inputs of several participants.

Communicative approaches in argumentative contexts can be summarized as interactive and dialogical, establishing a community of discourse.

These six issues are forming part of a whole, as represented in Fig. 5.1, their different dimensions combining in a synergistic way to support argumentation in science classrooms. The students take on these roles of knowledge producers because the curriculum (task, resources, etc.) requires them to do so. They are supported in them by the teachers' performances and modeling. The collaborative and dialogic approach provides an adequate context for sharing evaluation criteria. Reflection about knowledge and about learning is built in the tasks. As a summary, argumentation is a skill that is learned through practice. Argumentative environments are a type of constructivist learning environments and share many characteristics with them, but they feature an emphasis on the evaluation of (scientific) knowledge claims.

Promoting Argumentation through Explicit Teaching

The focus of the previous section is on the common features shared by a number of learning environments, as documented in argumentation studies. In other dimensions these contexts exhibit a considerable diversity. One is the target students, ranging from primary (e.g., Eichinger et al., 1991; López & Jiménez, 2002; Mason, 1996) to secondary, in a majority of studies, and university (e.g., Kelly & Takao, 2002; Sadler & Zeidler, 2005). Another difference is in the choice between fostering argumentation through explicit formal teaching or by designing an environment in which argumentation competencies are embedded in the classroom culture and learning tasks. It is worth noting that these two options are complementary, as classrooms where argumentation is taught are also environments where the design principles involve the development of argumentation skills. On the other hand there is a continuum of practices that may count as teaching argumentation, from the formal introduction of rubrics about argument components, structure, or quality, to requiring students to justify their claims, although some authors would describe the second as teaching and others as not teaching argumentation. And it has to be acknowledged that the focus of a number of studies is on reporting argumentation rather than on how to promote it. This section discusses some instances of explicit teaching of argumentation and the next, classroom environments fostering it mainly through design.

One of the first studies exploring the effect of teaching argumentation in science classrooms was Kortland's (1996, 2001) doctoral dissertation about secondary school students' (aged 13–14) decision-making on waste issues. A first trial of the teaching sequence showed the limitations of the students' arguments, and additional activities were designed for the second year of the study, with the purpose of "have students arrive at the formulation of the requirements an argued point of view should met" (Kortland, 2001, p. 95). The tasks required students to criticize several arguments about the choice of a milk container and, from these criticisms, to derive the requirements of a well-argued position. It proved to be extremely difficult, and the students were not able to produce the requirements. The comparison of the argumentations patterns before and after the intervention showed a limited effect on the quality of the student's argumentation, although some improvement was found on the validity and clarity of the criteria used in order to make the choice. Kortland (1996) attributed this limited effect to the lack of attention paid to ensuring students' reflection on their own arguments.

With a stronger emphasis on reasoning patterns, Zohar and Nemet (2002) examined the outcomes of a unit integrating explicit teaching of argumentation with genetics content. Argumentation skills were addressed in a lesson focused on argument structure and on criteria for distinguishing between good and bad arguments, and in the context of each genetics dilemma. The 12-hours teaching sequence created intensive opportunities to exercise these skills (Zohar, 2004). Three qualitative categories were used for the assessment of argumentation skills: (a) the capacity to formulate an argument, defined as a conclusion supported by at least one relevant justification; (b) the number of justifications; (c) the structure of the argument, the branching of reasons (see Zohar, 2004, p. 67 for a detailed description). Zohar and Nemet (2002) reported the enhanced performances of the students in the experimental group, both in biological knowledge and in argumentation. The improvement in argumentation skills was extended to transfer to everyday dilemmas. The authors interpret the significant gains produced by only one lesson about argument structure as supporting Kuhn's (1991) contention that argumentation skills (at least implicitly) are initially present, although not fully developed, and that the educational challenge is to reinforce them. Zohar and Nemet explain the changes, on the one hand as the effect of metacognitive thinking, defined as being conscious of generalizations, principles and standards of one's reasoning processes; and on the other for the changes in what was valued in the culture of these science classes.

A study with a focus on teaching argumentation was conducted by Osborne et al. (2004a) over two years, its first phase having as a goal to develop materials and strategies to support argumentation in the classroom, as well as teachers' development with teaching it (Simon et al., 2006). In the second phase, teachers taught nine lessons involving argumentation, and the progression in students' capabilities along the year was assessed, and contrasted with the capabilities in control groups. The teachers' use of argumentation experienced significant development and the quality of students' argumentation improved. The methodological developments for argumentation analysis are discussed in Erduran (this book).

For Osborne et al. introducing argumentation requires a shift in the nature of classroom discourse, changes both in the epistemological and social structures of the classrooms. About the epistemological structure, they propose strategies that have at its core the requirement to consider plural accounts rather than singular explanations of phenomena. About the social structure, to foster student–student interactions and dialogic discourse, these authors have developed a set of frameworks that enable to generate argument-based lessons. Some instances are:

- *Experiment report*: Students are given a record of another student's experiment and conclusions, written in a way that could clearly be improved, and asked to produce ways to improve it and explain why.

- *Competing theories*: Students are introduced to a physical phenomenon and offered two competing explanations together with a range of pieces of evidence that may support one of the theories, both or neither. They are asked to evaluate each piece and use it to argue for one of the explanations.

A further outcome of this study with the goal of supporting teachers' competence in teaching argumentation (Simon et al., 2006), is the IDEAS project for professional development, a programme which produced a set of video-based resources for teacher training (Osborne et al., 2004b).

In a study examining the use of evidence in written arguments, Kelly and Takao (2002) analyzed scientific papers by university students. The oceanography course was also an intensive writing course, including instruction about the technical paper genre, for instance how scientists select a problem, how evidence is used to support a theory or model, or how observations are separated from interpretations. The specific challenges posed by written arguments and the outcomes of the study, in the wider context of a research programme, are discussed in Kelly et al. (this book).

In a perspective linking argumentation to inquiry instruction viewed as cognitive apprenticeship into scientific practice, Sandoval and Reiser (2004) reported the use of a learning environment scaffolding epistemic aspects of inquiry and guiding students in the construction and evaluation of scientific explanations. This work has been extended, in one direction by Sandoval and Millwood (this book), with an exploration of students' practical epistemologies and use of evidence. In a related direction, Reiser and colleagues (Kenyon et al., 2006; Kuhn & Reiser, 2007) enhanced the instructional framework to support students' epistemological understanding and reasoning about evidence. Kenyon et al. aimed to provide students with tools—in the format of epistemological criteria—on which to base their evaluations of knowledge claims. Argumentation was fostered both by explicit instruction, rubrics and sample questions, and by being embedded in the design of activities (L. Kuhn, personal communication). The authors attempted to get the rubric produced by the 7th-grade students, but this proved too difficult, and finally the teacher gave them criteria for claim, evidence and reasoning—that were turned into a scoring rubric used by students to assess their quality. These difficulties of the students in producing criteria are consistent with Kortland (2001) results discussed above. As an instance, the criteria for evidence are: the evidence (a) is specific; (b) came from data, not opinion; (c) there is enough; and (d) supports the claim.

In a study exploring the potential relationship between the practice of scientific argumentation and traditional classroom practices, Kuhn and Reiser (2007) compare classroom interactions in contexts that do and do not explicitly support argumentative discourse, concluding that although scaffolds such as teacher and written prompts can positively influence students' argumentative products, these supports have less influence over the process of argumentative discourse, which is more heavily influenced by the existing classroom culture, such as the ways in which the teacher responds to student ideas.

The efforts of different research teams in developing and implementing computer-based learning environments to promote argumentation are reviewed by Clark et al. (this book).

From this review of representative studies on explicit teaching of argumentation, some patterns could be discerned. First, the need for extended time, either repeated argumentation sessions during a term (Osborne et al., 2004a), or activities in a long teaching sequence (Kelly & Takao, 2002; Kenyon et al. 2006; Kortland, 1996; Kuhn & Reiser, 2007; Zohar & Nemet, 2002): argumentation needs practice. Second, although the development of criteria by the students seems a desirable goal, it proves to be extremely difficult (Kenyon et al., 2006; Kortland, 2001): in this, as in other dimensions, the teacher's scaffolding plays a crucial role. Third, in all the cases explicit teaching of argumentation was coupled with support through teacher's strategies, task design and classroom climate; some authors argue that one strong influence (Zohar & Nemet, 2002) or even the strongest one shaping argumentative discourse (Kuhn & Reiser, 2007) was the classroom culture. Studies about argumentation promoted through particular classroom cultures are examined in the next section.

Promoting Argumentation through Classroom Culture and Intellectual Ecology

In a number of argumentation studies the results show students engaged in argumentative reasoning and, in the absence of explicit teaching of argumentation, the question arises about what dimensions in the task, teacher strategies, classroom climate, or a combination of these, may promote their argumentation competencies. We (Jiménez-Aleixandre et al., 2005) have framed this question in Toulmin's (1972) notion of *intellectual ecology*, defined by him as coexisting ideas and features of the social or physical situation that provide a range of opportunities for intellectual innovation. Some instances of argumentation promoted through a particular intellectual ecology and classroom culture are discussed below.

A seminal classroom study about argumentation in science is Eichinger et al. (1991) with 6th-grade pupils, which combined the examination of argumentation analysis, scientific content and social norms. Working in small groups, students had to decide about which state (i.e., solid, liquid, gas) was better suited to transport water in a space ship. They had previously studied the relevant concepts, weight, volume, molecular structure of water in its three states, but all the pupils except Emily had great difficulties to apply them to solve a practical problem. The authors contend that, although the outcomes may seem an instance of social construction of knowledge, for the students, without the teacher's intervention, progressed from random proposals to a relatively sophisticated argument supported in the justification about volume, the agreement was strongly influenced by social interactions. After the two leaders maintained opposed positions—one of them decided to support Emily, the student who advanced the appropriate justification.

A longitudinal study of elementary pupils' reasoning and knowledge construction from 4th to 5th grades in Italy, is reported by Mason (1996, 1998), with a focus on the role of oral and written discourse. Data were gathered in five classrooms where innovative learning contexts were designed as part of an environmental education project having as a goal conceptual change. Primary school pupils engaged in argumentation processes and epistemic operations, took responsibility for their knowledge claims, supported them with reasons and warrants, appealed to counterevidence, and reflected metacognitively (Mason, 1996). Some features of the classroom environment were: the pupils were encouraged to reflect about their own understanding in written reports, to compare and evaluate ideas about ecology; the teachers promoted argumentative reasoning and, through their interventions in the debates, favored the structuring of the cooperative thinking processes; the classroom discourse was dominated by true dialogue; the organization in small groups promoted a learning community characterized by collaboration and public sharing of ideas. The author concludes that in classroom discussions the students can practice reasoning skills and that "Deeply involved in taking charge of their own processes of knowledge construction, students enter a kind of cognitive apprenticeship to scientific reasoning and argumentation" (Mason, 1996, p. 431).

Part of a research programme collecting ethnographic data during three academic years in a high school physics classroom, a study by Kelly et al. (1998) examined the use of evidence, the range of warrants and the conditions leading to warranted arguments while students completed electricity performance assessments in pairs in a laboratory. The students were not given opposing views nor told to argue, but rather the naturally occurring conversations were studied. The authors see conceptual ecology (this name, rather than "intellectual ecology", has been circulating in the conceptual change literature) as constructed among the participants, including current knowledge, epistemological commitments, analogies and metaphors. In this course the students acquired data using computers, and designed, tested and presented scientific projects (e.g., technological devices, scientific papers or posters). Three dimensions of warrants emerged from the analysis: (a) strategies, for instance direct justification through a warrant, or subsequent justification, offering a second argument as warrant; (b) referents, empirical or hypothetical; and (c) types, declarative or comparative. About the conditions leading to warranted arguments, the more frequent were data, either anomalous or expected; claims by a partner, including challenges; and questions. Kelly and colleagues suggest that supposed common knowledge could make warranting unnecessary. They also found both instances of conclusions consistent with canonical science, but reached through faulty warrants, and of warrants consistent with science used in support of incorrect claims, suggesting the need for an analysis more connected to subject-matter (as for instance undertaken in Kelly et al., this book).

The RODA (ReasOning, Debate, Argumentation) project evolved from examining the balance among the cultures of "doing school" and "doing science" in the classroom discourse, and the effect of tasks which required reasons for claims on argumentation development, in a context where it had not been taught (Jiménez-Aleixandre et al., 2000), to exploring, through classroom studies, the connections among argumentation and different dimensions of science learning, concept construction, designing experiments in the laboratory, development of attitudes. For instance Jiménez-Aleixandre et al. (1999) examined the process of data construction by high school students in a microscope task requiring them to identify an unknown sample: the students interpreted and reinterpreted their observations in the process of appealing to empirical data to back their claims. The authors compared the students' actions with other groups working in standard microscope assignments, noting for instance the interactions with sources of knowledge in books and notebooks, not observed in standard laboratory sessions.

Results from a longitudinal study about argumentation and environmental education in primary school from 4th to 6th grades (9–12 years), also part of RODA, are reported in several papers. The methodological approach of the classroom and of the whole school attributed a great share of responsibility to pupils, from classroom organization, and issues to be studied to the evaluation of the goals of teaching sequences (López & Jiménez-Aleixandre, 2002). The process of transformation of proposals for their own code of behavior in a field trip, showing the pupils engaged in true dialogue, and the teacher strategies for encouraging pupils' taking charge of their learning and reorienting the debates, is discussed in Jiménez-Aleixandre and López (2001). The quality of 4th-grade students' arguments along 10 sessions is analyzed in Jiménez-Aleixandre et al. (2005), and given the sophistication of arguments including rebuttals, the question arises of what features in the classroom environment supported the development of argumentative competencies. To examine it, we use Toulmin's (1972) notion of *intellectual ecology* and propose four intertwined dimensions in it: (a) *pedagogical*, including categories as teacher's style and strategies (showing interest in pupils' proposals, reformulating them), classroom climate, placing responsibility in the hands of students, sharing the authority to evaluate; (b) *cognitive* and metacognitive, including students' reflections about their control of learning, about learning as a holistic process, about the process of inference, challenges of book authority, reflections on uncertainty; (c) *communicative*, including interactive and dialogic interactions, analogies and metaphors; and (d) *social*, including the influence of leadership, competition and cooperation in the co-construction of arguments. It is suggested that the sustained enculturation in this particular school and classroom culture provided the adequate environment for argumentative competencies to develop. The notion of intellectual ecology can be fruitful for studying these complex environments.

A classroom study focusing on high school students' argumentation about a socio-scientific problem of environmental management is reported in Jiménez-Aleixandre and Pereiro (2002, 2005). During 17 sessions the students, distributed in jigsaw groups, worked with real data sets, maps, technical projects and scientific reports in order to produce their own reports about the pros and cons of sewage network in a polluted wetland. They were required to support their claims, to critically process different sources of data and authority, and to reflect on the changes in their ideas from the beginning of the unit, referring to the data relevant in producing the changes (Jiménez-Aleixandre & Pereiro, 2005). The results show how they articulated relevant ecological and technical concepts with environmental values in constructing warrants, and how their criteria for evaluating claims became more refined and specific along the unit. The relevance of engaging students in life-size problems for their enculturation in a knowledge producing community is suggested. Another instance of RODA classroom studies is the exploration of the process of construction of meanings for the concept of neutralization, as it is used as a cognitive tool to solve a titration problem in the laboratory (Jiménez-Aleixandre & Reigosa, 2006), in term of contextualizing practices across epistemic levels, as for instance translating observational to theoretical language, or using concepts as resources to frame anomalous data.

An autobiographical study about the teacher's role in the management of argumentative role-play debates is reported in Mork (2006). A web-based teaching programme about wolves was used to achieve the goals of learning about ecology, about different viewpoints and solutions to the problem, and of practising argumentation. Working during six lessons, the students were required to deal with contradictory evidence and to provide justifications for their claims. Some types of teacher's interventions identified in the study are: 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. The author suggests the use of this typology as a guiding tool for teachers when promoting argumentative debates.

These are a few instances of studies about classroom environments promoting argumentation, and others are discussed by their authors in a number of chapters of this book (e.g., Duschl; Kelly et al.; Kolstø and Ratcliffe; Sandoval and Millwood; Simonneaux; Zeidler and Sadler). From this review, some patterns emerge, concurrent with the ones discussed in the case of explicit teaching. First, the relevance of extended time, sometimes involving sustained work along several years, as evidenced in longitudinal studies. Second, the role of the teacher's support. Third, the students taking responsibility of their learning processes and knowledge claims (e.g., Jiménez-Aleixandre & López, 2001; Mason, 1996). Fourth, the students' involvement in using data, designing projects, writing reports (e.g., Jiménez-Aleixandre & Pereiro, 2002; Kelly et al., 1998), and more generally in problem-solving and decision-making in small group. Fifth, the ways in which socio-scientific issues are appropriate to develop argumentation (Mork, 2006). Sixth, the students were encouraged to reflect about their own understanding and change in ideas and positions (e.g., Jiménez-Aleixandre & Pereiro, 2002; Mason, 1996).

Discussion: Engineering Cognitive Apprenticeship in Argumentation

The analytical review of studies providing empirical evidence on the design of learning environments effective in promoting argumentation, both through explicitly teaching it and through promoting it by means of explicit design and by creating an appropriate classroom culture, shows that besides a variety in the perspectives and in the features of the classrooms, there are a number of shared characteristics that suggest recommendations for teachers and science educators seeking to engineer cognitive apprenticeship in argumentation.

A first implication I would draw is about *what roles do we require from students* in argumentation environments: these studies point to students developing argumentation skills because these were required for their role in the learning process (Bereiter & Scardamalia, 1989). So, in general, argumentative competencies have an appropriate environment to develop in classrooms designed as learning communities where students work in authentic problems and are engaged in using data, collecting evidence, or producing reports; where students are protagonists of their own learning, features shared with other constructivist learning environments. And, in particular, in argumentation learning environments, students are engaged in supporting knowledge claims with evidence, evaluating claims, developing criteria for this evaluation, and other activities related to *knowledge evaluation*.

A second suggestion concerns the relevance of involving students in *reflection and metacognitive thinking*, encouraging them to compare their ideas and positions with alternative ones, or to evaluate the change in them and the causes behind this change. As discussed in Garcia-Mila and Andersen (this book), it has been claimed that developing metacognition is a key factor in the coordination of theory and evidence. They also point to the effectiveness of combining *practice* (as characterized in the previous paragraph) with *reflection*.

A third implication is the need for *extended engagement* in argumentative discourse. Argumentation needs to be practised for some time in different contexts, and anecdotal activities do not provide enough opportunities for reflection.

A fourth implication is about the *teachers' support* to students' development of epistemological understanding. The teachers model argumentation and inquiry, provide criteria for the evaluation of knowledge, translate epistemic goals into their contributions.

From the examination of studies promoting argumentation by explicit teaching of argumentation, as for instance explicit discussion about the criteria for evaluating arguments, and by explicit design of tasks, teacher strategies and classroom culture, it seems that their effects are difficult to separate. Studies about explicit teaching of argumentation as Zohar and Nemet (2002) and Kuhn and Reiser (2007), point to the influence of a classroom culture valuing the support of claims with evidence; for Kuhn and Reiser the classroom culture was the strongest influence. It can be claimed that both explicit teaching of argumentation and an intellectual ecology constructed in the classroom around knowledge evaluation, contribute to the development of argumentative competencies or, in Mason (1996) words, to students entering a cognitive apprenticeship to scientific reasoning and argumentation.

Designing learning environments to support argumentation in science classrooms is not an easy task. But potential contributions from argumentation, such as externalizing cognitive processes, developing critical thinking, supporting the development of epistemic criteria, and other discussed in Jiménez-Aleixandre and

Erduran (this book), may be worth the challenge. Argumentation can so contribute to the scientific education of learners and also to their education as citizens.

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