# Argumentation and Learning

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**Abstract** This chapter provides multiple perspectives on the intricate relations between argumentation and learning. Different approaches to learning impinge on the way argumentation is conceived of: as a powerful vehicle for reaching shared understanding, as a set of skills pertaining to critical reasoning, or as a tool for social positioning. Each perspective has harvested empirical studies that have stressed the importance of argumentation in learning. Methodological tools that fit the respective perspectives are reviewed. In spite of the pluralistic stance adopted, this chapter attempts to draw connections between the findings obtained in the different perspectives. In a separate part, it considers the specific role of argumentation in learning processes and outcomes for four subjects areas: in mathematics, studies are presented that show deep gaps between argumentation and proof. In science, experimental studies are reviewed to examine whether and how argumentation promotes conceptual change. In history, the chapter considers the role of argumentation in challenging narratives and in claiming a position. At last, we describe the new wave that characterizes civic education programs towards the instillation of argumentative practices in democratic citizenship.

**Keywords** Critical reasoning, Shared Understanding, Learning from interaction, Emergent Learning

## 1 General Introduction

Writing an essay on argumentation and learning is not only difficult because of the complexity of the processes involved but also because the terms "argumentation" and "learning" cannot be combined without reflecting on their very nature separately. The term "learning" is highly loaded, it means very different things for psychologists

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belonging to different traditions. Socio-cultural psychologists view learning as a process that emerges during interactions. Emergent learning is often conferred to a community that develops new practices that yield new outcomes (understandings, know–hows, etc.). Emergent learning is basically visible as it deploys in interactions among people, in the use of tools, etc. For others learning is a psychological change in the individual which is observed indirectly between successive activities. Researchers that study emergent learning focus on a large context – a community with a common motive in which individuals interact and use tools and technologies, while researchers that study learning as a psychological change focus on individuals. This choice is not indispensable and we will see later on that it is a fact problematic. Since in this chapter learning is considered in a context for which the process (argumentation) and the object (argument) are two sides of the same coin, scrutiny over community in context and over individuals are both relevant. From a theoretical point of view, though, the two views of learning have been considered as incompatible (for example the controversy about "situated learning" in Greeno 1997). Our approach on this controversy will be ecumenical for a simple practical reason: we wished to review research on argumentation and learning and since it is partitioned among the two camps, we were obliged to report on their findings. In several places of this chapter we try to conciliate between them, especially when they seemed to lead to contradictory conclusions. However, an overarching theoretical effort is still to be done. Within the more modest limits of this chapter, since we used the same term, learning, with two different theoretical meanings, we distinguished between the meanings intended by qualifying the first as *emergent learning* and by using the plain term "learning" to refer to a psychological change in the individual.

## 2 Learning to Argue and Arguing to Learn

The relations between argumentation and learning are complex. This complexity depends in the first place on the multiple facets of argumentation. In the chapter "Argumentation as an Object of Interest and as a Social and Cultural Resource," Rigotti and Greco (this volume) described many of these facets. They raised the term "reason" with its ambiguous meaning as well as the term ratio to characterize a way to think, a relationship between reason and language. In contrast, argumentation was also presented as a tool to achieve goals, arguing in order to understand, clarify a doubt, decide, solve a conflict, amplify knowledge, etc. The relationships between learning and argumentation are then at least twofold. It may consist of learning to reason, to explain or to challenge. On the other hand, it may consist of learning to achieve a specific goal through argumentation. In their book, *Arguing to Learn*, Andriessen et al. (2003) make this distinction clear: "Learning to argue" involves the acquisition of general skills such as justifying, challenging, counterchallenging, or conceding. In contrast "Arguing to learn" often fits a specific goal fulfilled through argumentation, and in an educational framework, the (implicit) goal is to understand or to construct specific knowledge. Do we mean to focus on how people learn to argue, or rather on how people learn through argumentation? They presented the two directions as alternatives. Are these two directions exclusive, though? When one counterchallenges her peer in a discussion, such a move reveals a skill, counterchallenging, and its "content," the reason invoked to justify an argument previously raised, and by such strengthens argument. Learning to argue and arguing to learn are then not independent. Rather, they are intertwined and often seem inseparable when we observe discussions in classrooms. However, this distinction is helpful to identify the aims of researchers in the studies undertaken so far on learning and argumentation. We organize then this chapter along with this distinction for the sake of clarity of presentation. In some cases, the researchers themselves were explicit about the inseparability of argumentation as a tool and its object in learning processes. This happened with several psychologists with a socio-cultural tradition according to which the context of action is apprehended in a broad sense.

## 3 Learning to Argue

Developmental psychologists have studied the ability of children in natural settings such as disputes or negotiations. In these contexts, children know how to argue very early. Three-year-old children know a lot about the form, content, and function of arguments in verbal interactions, and by the age of five are skillful negotiators with their parents, siblings, and peers (Eisenberg and Garvey 1981; Maynard 1985; Stein and Trabasso 1985). These findings conflict with very broadly cited studies by Kuhn (1991, 1996) and Nickerson (1986). In her 1991 study, Kuhn interviewed four age intervals to sample: teens, 20s, 40s, and 60s about urban social problems (e.g., "what causes prisoners to return to crime after they're released?"). The interview consisted of eliciting and probing the subject's reasoning about these problems. Subjects were elicited and probed to express their causal theories, to justify them by providing supporting evidence, to generate opposing theory, to evaluate presented evidence, and to answer epistemological questions regarding certainty and influence of the evidence on their own thinking. This study and other studies by Kuhn and by Nickerson showed that people tend to provide theories with a single cause or with multiple parallel causes. Concerning evidence, people had difficulties differentiating between theory and true evidence to often express "pseudoevidence." From a developmental perspective, teens and elderly persons have more difficulties to evaluate evidence, and their judgment is biased by their own standpoint. Also, all age interval samples – even adults, have difficulties in elaborating opposing theories. People at their 20s are the most skillful in this respect. Also there is a clear advantage to more educated persons. The superiority of educated persons was the most pronounced for epistemology. Another interesting finding is that the mastery of skills is quite stable over the social problems that were checked. Such stability confers to the "argumentive skills" (according to Kuhn's terminology) a status of "general skills" that develop in the life span. In summary, Kuhn's studies (1991, 2001) showed that in the sixth- to the ninth-grade period, argument skills grew in children. After that, educational level made the difference, with college-educated people performing better than ninth graders, but with people without a college education performing at a level between sixth and ninth graders. Kuhn (2001) identified developmental differences according to a three stage development of epistemological understanding: *absolutist*, in which knowledge consists of facts, *multiplist* or *relativist*, in which knowledge is regarded as an opinion, and *evaluativist*, in which claims and support are acknowledged. The influence of Kuhn's studies on research in learning to argue has been substantial since learning can be measured by the increase in argumentive skills scores and since the tools proposed are relatively simple to use (Zohar and Nemet 2002).

Stein and Miller (1993) provide theory and findings that help overcoming the contradictions between the natural propensity children have in engaging in argumentation and biases in argumentive skills. According to Stein and Miller, although argumentation skills emerge very early in development, knowledge about the function, form, and content of argument "emerges out of a desire to ensure that personally meaningful goals are attained" (p. 101). Stein and Miller introduce emotion in argument contexts to assume that four components underlie the development of an argument (1) the desire to achieve personally meaningful goals, (2) knowledge about the positive and the negative consequences of actions, associated with the attainment of these goals, (3) knowledge about obstacles that stand in the path of goal attainment and (4) beliefs about consequences of not attaining these goals. In that way, understanding the nature of personal goals allows predicting the thinking, reasoning, and actions carried out during attempts to resolve conflicts. When children recognize that they have conflicting views, both willingly engage in an argument and both aim at settling it (by wining or by reaching an agreement).

The contradiction between the developmental studies undertaken by Kuhn and by Stein and Miller can also be settled through a different but complementary argument. This argument belongs to the methodological realm. In checking learning to argue, those scientists evaluated argumentative skills. In the two kinds of studies, the methodological tools were of very different nature. For Kuhn (and Nickerson) these were structured interviews or questionnaires administered at different ages (for developmental studies) or before and after an educational treatment. In these questionnaires or interviews, students are typically asked about social issues in order to check whether their ability to give reasons, to produce evidence that corroborates them, to imagine challenges and to rebut them, etc. increases (Kuhn 1991). Similar tools similar are used to measure the success of educational programs to check the acquisition of skills. For example, Zohar and Nemet (2002) used such questionnaires in similar scientific issues to show that during a program on genetics and ethics in which a teacher scaffolded argumentative skills through explicit prompts, the learned argumentative skills could be applied in near transfer and far transfer tasks. On the other hand Stein and Miller directly observed children when settling disputes or negotiating a decision. The ability to challenge or to counterchallenge was observed in situ, not like for Kuhn in interviews in which an experimenter asked questions such as "Could you imagine how you could answer to somebody who does not agree with you? Give reasons" It is then clear from a theoretical point of view that the implementation of argumentation skills is highly sensible to context. A reasonable interpretation of educational studies that evidence "the acquisition of some argumentative skills" is that intensive programs in which students receive argumentative prompts turn to normative the enactment of argumentative practices in the specific context in which these practices developed.

The suggestion that argumentative skills can be differently enacted through manipulations that modify the goals of subjects has been confirmed in a recent study by Glassner and Schwarz (2005). Glassner and Schwarz investigated what they called the antilogos ability, an argumentative skill that consists of critically evaluating whether information presented actually supports a given claim. The antilogos ability was tested for different variables: age group (Grades 8 and 10), direction of information (one text was presented as supporting a claim and the other was presented as opposing the same claim), whether or not a personal argument is constructed before critical evaluation, and whether or not a worked-out example is provided before critical evaluation. The study indicated that (a) antilogos develops during adolescence; (b) it differs for different directions of information; (c) the combination of expressing personal argument before critical evaluation and being provided a worked-out example improves antilogos performance in Grade 8 students; (d) personal standpoint can be neutralized during critical evaluation. This study indicates both a developmental trend and the fact that context can considerably modify the manifestations of this skill.

## *3.1 Implications of Research on Learning to Argue on Education*

The research we overviewed has very important educational implications, on the role of school to foster argumentative skills. School should be sensitive to providing adequate contexts for argumentation. In general, the effort of the educator should be put on (1) designing situations in which the personal goals of the students (implied by the design) will help them engage in situations with educational value, (2) help students in identifying the goals of all participants. Another insight is that the explicit teaching of argumentative skills is often valueless: since students acquire basic argumentative skills very early, what is more needed is to contextualize these skills in educational settings. Schwarz and Glassner (2003) have described the asymmetry between everyday life and scientific argumentation through personifying everyday argumentation by a blind person and scientific argumentation by a paralytic person: The blind – the everyday arguer, can operate argumentative moves (can walk) but the result of the negotiations is often unclear – he/she does not know exactly where to go. The paralytic – the scientific arguer, receives principles, laws, theories; he/she can see them, but is not able to move on with them, to use them in further activities. This is then the job of the educator to design activities, and to provide tools with which the natural propensity to engage in argumentation could be capitalized for scientific issues.

This kind of result puts to the fore the importance of education and suggests that when Kuhn showed that "argumentative skills" are more elaborated among persons that learned at university, this does not necessarily mean that these "skills" characterize people who (will) go to the university but simply that students can learn to use argumentative skills naturally deployed in everyday discussions, in formal settings (such as interviews) and when they are invited to discuss scientific issues.

Educational programs generally do not put to the foreground of their rationales the fostering of argumentation. Rather, many educational programs are dedicated to promote "critical thinking" but their implementation heavily depends on the instilment of argumentative practices. Still, the variety of these programs is immense. Since, as we pointed out, argumentative practices are highly sensible to the goals of the participants (and of course, among them the teacher), it is important to identify the ideologies that underlie educational programs fostering critical thinking and argumentation. For example, in Perkins' Point Zero program, the learning to argue is realized through explicit coaching that express an ideology that considers education to think as the acquisition of thinking skills similarly to an apprentice that acquires craft in a workshop. And indeed, students are coached to express argumentative skills which are generally considered as meta-cognitive skills in a cognitive apprenticeship setting. One of the most celebrated programs dedicated to critical thinking is Lipman's "Philosophy for children" (P4C) (Lipman 1991) in which students are presented issues with a (folk) philosophical character and that are relevant to society. According to his ideology, critical thinking concerns understanding and not skills. The understanding is realized through dialogues among students, and dialogues between students and the teacher. Mercer's "Thinking Together" program (Dawes et al. 2000) concerns another ideology, the fact that education to thinking should focus on fostering dispositions rather than skills or understanding. Concerning argumentation, students are invited to comply with ground rules about what they call "exploratory talk" (and which could be called also critical reasoning). These rules are well known by students but they must enact them during classroom discussions. The role of the teacher is to sustain collective talk according to such ground rules. These three programs for fostering critical reasoning are quite archetypical. They differ strongly according to their ideologies and such ideologies induce different kinds of argumentation. Although we favor plurality (we are more sympathetic to an understanding-dialogic ideology, though) it is imperious to evaluate the programs that foster "learning to argue" with tools that fit their underlying methodology. For example, while P4C is clearly a program whose ideology concerns understanding, its impact has been measured by using tools pertaining to the acquisition of skills ideology. This is probably for this reason that, although the P4C program seems a sophisticated and extremely well-designed program, its evaluation shows mixed results: the tools for evaluating the P4C program are generally tools that fit a "skill acquisition methodology."

## 4 Arguing to Learn

In comparison with "Learning to argue" the volume of research and of educational initiatives that focus on argumentation as a tool for learning specific content is much more voluminous. In the two last decades, theoretical, empirical, and design efforts have been invested in this direction. We review first the theoretical work that has been done. This review is important since it impinges on empirical studies as well as the setting of learning activities. We then review empirical studies that have general implications on the relationships between argumentative activity and learning. Such studies have given birth to tools and strategies that may afford productive argumentation. In the last subsection we review research on argumentation and learning in specific domains, mathematics, science, history, and civic education.

## *4.1 Theoretical Underpinnings: Why Argumentative Activities Can Lead to Learning*

The various definitions of argumentation point at social as well as cognitive aspects (e.g., as defined by van Eemeren and colleagues – see chapter "Argumentation as an Object of Interest and as a Social and Cultural Resource"). We will see that from a theoretical point of view, each of these aspects should lead to learning.

According to the cognitive aspect, argument generation, whether in solitary or group format, causes a person to ponder the explanations behind solutions or perspectives, and requires him/her to express them in verbal, explicit communication. Such an act taken in isolation is also a self-explanation whose generation would be expected to lead to the "self-explanation effect" (Chi 2000, Chi et al.1989, Chi et al. 1994, Neuman and Schwarz 1998, 2000): the act of epistemic examination of one's personal theories and the reasons behind them is considered to improve understanding and knowledge construction processes (Baker 1999, Chi et al. 1989, Kuhn 1991). However, argument generation in an argumentative activity conveys more than an explicit verbal articulation of theories and their reasons per se. The verbal articulation is directed to another person, and may further encourage clarification of contradictions and faults in one's understanding, especially when communications are aimed at convincing others. In fact, research on accountability effects has shown that even the mere anticipation of an unknown audience that might require explanations or justifications has been found to improve a person's quality of thinking (see for example Tetlock 1992). Thus, this type of nondialectical or one-sided argumentation alone is expected to yield cognitive gains.

In addition, dialectical argumentation requires, by definition, the examination and coordination of different perspectives. Participants are forced to acquire new information about the topic under consideration, since they are exposed to a multiplicity of ideas and encouraged to explore the validity of each of these ideas. This means that they have to consider objections to their personal theories and assumptions, to attempt to understand alternative positions and to formulate objections and/or counter-objections (Stein and Miller 1991). Thus, the mere effect of exposure to and creation of more relevant information in argumentative contexts would alone be expected to lead to better learning results. In addition to such cumulative effects, however, the dialectical dimension of argumentative interaction is thought to have considerable qualitative advantages. First of all, when engaged in exploring the reasons why a certain theory is faulty, it not only allows one to propose convincing arguments to refute that position in a discussion, but it also deepens his/her understanding of the correct concept in the process (see also Kuhn 1992). Secondly, argumentation's unique structure of linking premises, conclusions, conditions, rebuttals, and so forth is also thought to considerably improve and extend the organization of knowledge, which leads to better recall and understanding on subsequent test occasions (Means and Voss 1996). This claim is further supported by current theoretical models that regard human thinking and the organization of knowledge presentations as mainly argumentative in nature (see e.g., Antaki 1994, Billig 1996). Accordingly, dialectical argumentation may be conceptualized as a tool, whose particular form provides a supporting and organizing structure to examine, evaluate, and elaborate on different ideas and to reach a solution.

Argumentative formats of reasoning are, furthermore, likely to significantly reduce some of the extensive cognitive load that is involved in learning, especially in tasks that involve cognitive conflict techniques. The individual cognitive load may be reduced by collaborating with other persons, through the combination of individual resources and the distribution of task-related cognitive demands among the participants. The dialectical dimension of argumentation, however, may provide an additional advantage to mere peer cooperation: Instead of having to represent the different views in one's mind and to elaborate, evaluate, and integrate them, an argumentative group discussion enables the objectification of perspectives and their representation by actual persons defending them (Baker 2003). Such an effect would be expected to significantly reduce the cognitive load.

So far, we mainly considered the cognitive aspect of argumentation and how this aspect may facilitate learning. We considered the individual at the center, the peers helping in elaboration of knowledge. The social aspect of argumentation was considered through the individual. A first very general potentiality of the social role of argumentation in learning concerns the fact that argumentative activities include practices for which participants feel highly engaged and motivated. They are committed to convince, or to understand, and to present personal views. Several researchers (e.g., Rogoff 1990, 1998) have regarded argumentative discussions as settings through which shared understanding emerges, testimony to the fact that the active engagement to share ideas takes place. Miller (1987) explained why argumentation achieves shared understanding and learning. In a theoretical analysis, Miller explained that three cooperation principles of argumentation provide the coordination that leads participants toward a set of collectively valid statements: generalizability, objectivity, and consistency. A statement is justifiable (generalizable) if it has been immediately accepted by the participants or if it can be traced back to other statements that have been immediately accepted. The status of statement may change for the collective according to the principle of objectivity: if a statement cannot be denied, it becomes collectively valid. Consistency, the third principle, precludes the acceptance of contradictions in the realm of the collectively valid. This interesting analysis is theoretical, though. It adds to the Vygotskian general idea of internalization (Vygotsky 1981):

"The higher functions of child thought first appear in the collective life of children in the form of argumentation and only then develop into reflection for the individual child" (p. 157). It also adds to a contemporary formulation of Vygotskian ideas, the idea of *participatory appropriation* (Rogoff 1993): "the process by which individuals transform their understanding of and responsibility for activities through their own participation… participation is itself the process of appropriation" (pp. 150–151). However, such ideas do not rely on fine-grained studies that scrutinize relations between social and cognitive aspects in argumentative activities. They are not specific enough. We will see later on in this chapter how Cobb and his colleagues, who adopted this socio-cultural stance, successfully described how collective argumentation led to autonomy of individuals and in participation of the emergence of new mathematical practices. Cobb and colleagues propose the term "taken-as-shared'" understanding instead of "shared understanding" to preserve a psychological aspect in his analytical method to analyze classroom activities. However, in the teacher-led discussions that took place in classrooms according to a careful design, talk was always argumentative.

We claim that it is imperious to be sensible to different types and patterns of engagement, and fine-tuned coding systems for identifying claims, counterarguments, evidence, conditions, justifications, etc in order to analyze learning processes stemming through shared thinking. As Teasley (1995) mentioned: "(…) simply having a partner and talking a lot will not improve learning. What seemed to be crucial to learning [in this task] is that children produced the types of verbalization that supported reasoning about theories and evidence" (p. 219). We argue, therefore, that it is imperative to distinguish between different types of discourse and to identify different argumentative interactions, to test their relations to learning. Theoretical considerations and empirical studies on this issue are still in an embryonic stage. Some speculations on the recurrence of argumentative formats similar to Bruner's formats for language acquisition (Bruner 1982) and on the formation of corresponding "topoi" – general understandings deriving from the regularities in meaning emerging from the participation to these formats have been raised by Krummheuer (1995). However, these are only speculations so far.

Several teams have entered a more modest path, but also more realistic for now, the characterization of talk or dialogues according to holistic features, and the empirical study of correlations between the engagement in such dialogues and subsequent learning. Mercer, and Wegerif (Mercer 1995, Wegerif et al. 1999) distinguished between cumulative, disputational, and exploratory talk, the latter being responsible for (emergent) learning and change. Asterhan and Schwarz (2007) discerned between two-sided argumentative dialogue, one sided argumentative dialogues and nonargumentative dialogues to correlate them to subsequent learning gains. Although this approach – the analysis of different types of talk, has constituted a decisive step for the empirical study of arguing to learn, it has not led so far to a real breakthrough in the understanding of learning mechanisms emerging from recurring argumentative formats.

## 5 General Review on Research on Arguing to Learn

Research on arguing to learn can be classified according to the methodological paradigms used to observe it. The first method is indirect. It concerns observing students in subsequent activities in which observation is more convenient – generally in tasks given to individuals. We show then that in order to be effective in studying arguing to learn directly, one should first discern between types of talk. We then report on studies that describe emerging learning in argumentative talk. We conclude by suggesting that the two methodological paradigms should be merged although such an effort did not succeed so far.

### *5.1 Studies of Learning in Activities Following Argumentative Interactions*

Among the theoretical reasons for learning outcomes in and from argumentative activities, the Vygotskian idea of internalization of social interactions is the most popular. It is then natural to trace learning in activities after argumentative interaction. The types of activities that have been used for this purpose are diverse: from simple expression of attitudes/opinions (e.g., after a discussion), to structured interviews or argumentative writing of essays. The timing of these activities is also diverse: from immediate tests to tests after several weeks. In most of those studies the aftermath activity involves individuals; the research question concerns "effects of interaction on individuals." The argumentative writing of essays is problematic since the biases and weaknesses in content and structure of written arguments may be attributed more to the difficulty to engage in the argumentative writing process itself than to shortcomings in the participation of students to a previous argumentative activity. Also, gains from argumentative interactions may stem from the writing process itself that demands to a very rich cognitive activity. In spite of these caveats, written arguments are nevertheless used to measures gains from previous argumentative activities (Kuhn et al. 1997, Schwarz et al. 2003, Sandoval 2003). This kind of methodology is justifiable though, if the researcher keeps in mind that the written argument is the product of two activities, the argumentative interaction, and the writing process.

Several methods have been developed to analyze argumentative texts. The most obvious analysis concerns change of standpoint or of attitude. For many contents (e.g., in social issues) change in standpoint does not occur as a result of argumentative activity and learning should be identified in more subtle features of the written text. The second most common method is structural: it consists of identifying Toulmin components in the written text: What students cite as evidence to support their claims, or how do students make warrants rhetorically and how do they refer to data within explanations (Sandoval and Millwood 2005). Another method concerns an evaluation of the form of the written text (also called the argumentative level of the text). Mani-Ikan (2005) integrates ideas by Means and Voss (1996) and Kuhn (2001) to propose five levels:

*Level 1.* Unwarranted: unsupported claim/s.
*Level 2.* One sided: an argument containing claims and reasons for only one point of view.
*Level 3.* Multiplist: an argument containing claims and reasons for opposing points of view or stand, without deciding between them.
*Level 4.* Decided: an argument containing claims and reasons for opposing points of view, and a declared but arbitrary choice between them.
*Level 5.* Evaluativist: an argument containing claims and reasons for opposing points of view, and a choice between them, based on evaluation and confutation of the stand not taken.

Obviously, the level depends on the issue at stake and one may write a high-level argument for one issue and a low-level argument for another one.

There are nonstructural changes that concern less holistic characteristics of written arguments, for example certainty. Other changes are characteristic of specific contents: for example, it is valuable to observe change in empathy, agency, and plot scheme in history. To observe changes one has first to establish typical arguments.

These methodological precisions and caveats being made, we can exemplify now in two research papers, methods for studying learning through comparison of texts written before after argumentative activities. Kuhn et al. (1997) investigated the effects of dyadic interaction on argumentive reasoning. They showed that if adolescents or adults were prompted to find consensus or to understand differences of opinions in successive interactions, argumentive reasoning progressed. The progresses were measured in written essays 6 weeks after interaction through identification of number of arguments, their quality (nonfunctional to functional), whether evidence was used, and holistic evaluation of structure of arguments (from one-sided to two-sided arguments). Kuhn et al. study showed interesting results: first the fact that the arguments in the final texts were more two-sided. Also, although opinions did not change, they turned to be more moderated among adolescents than among adults. Also, among subjects that changed from a one-sided to a two sided argument, the adolescents used meta-cognitive statements while the adults did not. The theoretical interpretation of this study is problematic, though: the written text of the individual is understood to represent the argumentative reasoning of the student on the issue. Another thorny issue concerns the nature of the activity designated as "dyadic interaction." Kuhn and colleagues recognized that in most of the dialogues, no conflict model dominated and that peers agreed in the course of their discussion. The term "effect of dyadic interaction" is then quite fuzzy. The types of processes during interaction are diverse, and some of them only were really argumentative. In spite of its problems, this study is valuable if instead of dealing with effects of dyadic interaction on argumentive reasoning, one interprets it as the study of argumentative characteristics of texts after dyadic interaction. This interpretation is adopted by Schwarz and colleagues (Schwarz et al. 2003) to show how triadic interactions improved the quality of argumentative texts written by Grade 5 students invited to write arguments on the issue of experiments on animals. The experiment comprised multiple stages in which students wrote arguments individually or collaboratively. At one of the stages, triads were presented short texts representing arguments pro or con the issue. Schwarz and colleagues showed that collective essays were of the highest argumentative quality and that the Grade 5 students did not use texts in their essays. In contrast with Kuhn and colleagues, Schwarz and colleagues concluded that knowledge about experiments on animals was co-constructed in argumentative activities (and not that argumentive reasoning increased). To illustrate their conclusion, Schwarz and colleagues analyzed some protocols to show the argumentative processes that led to changes in written texts. Like in the Kuhn et al. study, the processes showed more socialization than adversarial dialogues. In summary, the "effect" in both studies did not measure a correlation between a type of dialogue and quality of individual text writing but between a very general set of conditions – dyadic interaction, and instructions to seek consensus or understand disagreements, and individual text writing. The set of conditions can be called an argumentative design, as it is hypothesized to provide constraints and affordances for argumentative activity although actual argumentative processes are not guarantied.

Chapter "Argumentative Design" in the present book is dedicated to argumentative design. In that chapter, it is stressed that without a meticulous planning concerning tools, initial knowledge of the discussants, their social arrangement etc, talk is generally nonargumentative; argumentative talk emerges generally when structured by the teacher and/or by representational tools. The scarcity of productive argumentation raises an important issue from a research point of view: the measure of impact of argumentation on learning through analysis of a product after "argumentation" instigated through argumentative design is quite problematic. It is always necessary for the researcher to ascertain that argumentative talk really deployed during interaction as a result of the argumentative design.

## 5.2 *Differentiating Types of Talk: A First Step in the Identification of Learning in Argumentation*

We stressed that talk is far from being always argumentative. More than that, cognitive (internal) conflicts or (external) disagreements do not automatically trigger argumentative processes. For example, de Vries et al. (2002) have showed that argumentative talk is not common in learning scientific knowledge even in those conditions. However, these conditions facilitate their emergence. For example, in a pre-post design experimental study on conceptual change in inheritance issues, Williams and Tolmie (2000) found that children with dissimilar ideas were able to take more advantage from group discussions, than were those assigned to groups with partners who had similar initial ideas. Dialogue analyses of on-task group behavior, furthermore, showed that the two conditions differed not only in amount of intra-personal conflict, but also in the extent that collaborators engaged in negotiation and joint construction of ideas (see also Tessler and Nelson 1994, Kruger 1993).

However, the talk that developed uncovered shared thinking that was not necessarily argumentative. In other words, teachers or researchers cannot dictate the kind of talk that develops among peers, even through well-designed situations. The study of learning outcomes of argumentation by analyzing products of activities following argumentation is then overall problematic. The study of emerging learning in argumentative activities, which is a priori more complex, is then perhaps more promising, since it is conditioned by a prior identification of argumentative talk.

The widely cited study conducted by Lauren Resnick and colleagues (Resnick et al. 1993) is an excellent example of the intricate relations between these fields of research: Triads engaged in collaborative argumentation on nuclear power and gradually co-elaborated complex arguments. Learning here emerged in the interaction between interlocutors through the expression of argumentative moves (see also Leitão 2000; Pontecorvo and Girardet 1993). In this influential study, Resnick ostensibly did not discuss problems of emergent learning in the course of the discussion or of "learning gains" after discussion. The study brought to the foreground the deployment of reasoning in conversation and focused on the argument that was developed by the group. By concentrating on the development of collective arguments during conversation, however, she delimitated another domain to be studied by her followers: learning from conversation. What can be said on further activities at the individual level following collaborative reasoning activities?

## 5.3 Emergent Learning in Argumentative Talk

The study of emergent learning in argumentative talk has been especially done in the framework of collaborative problem solving activity. Such a framework is very far from "natural settings" as it demands careful design. A first approach to the study of emergent learning in argumentation has been proposed by Cobb and colleagues (Cobb et al. 2001) in mathematics classrooms. This approach, called "the analytic method," fits teacher-led discussions in elementary school mathematics classrooms. Each of the activities is carefully designed according to expected "learning trajectories" that concern "taken-as-shared" understandings of the group. Between activities, design is reassessed against data collected through triangulation methods. Emergent learning is first observed through emergent practices and the establishment of new socio-mathematical norms, then through the arguments raised and accepted by the group and by individuals. This sociocultural perspective is important for all scientists interested in observing learning in a rich context. However, when the focus is on argumentation, the relevance of this study is limited: For Cobb and colleagues, argumentation is part of the design: the teacher is committed to invite all children to participate, to explain or justify, to listen to and to attempt to understand others' explanations, to indicate when they considered solutions as invalid, etc. Talk was then considered to be argumentative overall inasmuch as the teacher was committed to instill these practices, although only in some of the protocols presented, students autonomously challenged and counterchallenged each other's solutions: Instead of characterizing any talk aimed at attaining shared understanding as argumentative, one should have a more precise scrutiny over the kinds of argumentative talk that govern classroom discourse.

When one discerns different kinds of talk, argumentative talk is not common, and the study of emergent learning begins by the identification of segments of argumentative talk. Baker (2003) has provided a detailed account of the emergence of learning in the framework of collaborative problem solving. Argumentative talk is triggered by the awareness of some diversity in the epistemic status of solutions: participants consider different solutions to the problem or have different beliefs about the solution (even they propose the same one). This diversity leads to an interlocutory problem in which participants try to transform the epistemic statuses of the solutions. According to Baker, this transformation proceeds through two complementary processes, argumentation, and negotiation of meaning. Argumentation functions in two ways. Dialectically, it enables linking different sources of knowledge through moves that strengthen or weaken epistemic statuses: we recognize here the construction of arguments and counter-arguments. Dialogically, argumentation induces roles (proponents, opponents) that bring forward theses. The role players interact according to ground rules of interaction that are partly logical and partly pragmatic and cooperative. The ground rules lead participants to agree on the outcomes to be retained. Negotiation of meaning is the process completing argumentation through which collaborative learning is realized. This is an interactive means to interpret preceding dialogues. Negotiation of meaning occurs in or near to argumentative talk in two ways: dissociating concepts and combination (or compromise, see also Perelman and Olbrechts-Tyteca 1958). It appears that dissociation and combination lead people to drop beliefs that are not well articulated and to accept beliefs whose definitions are more elaborated. Baker claims that such processes influence the epistemic statutes of solutions.

Schwarz, Perret-Clermont, Trognon, and Marro approach (Schwarz et al. 2008) to emergent learning is compatible with the approach proposed by Baker. Their method of analysis is inspired by the *Interlocutory Logic* developed by Trognon (1999) to trace learning in interaction: they identify the interlocutory force of all utterances and their propositional contents. The interlocutory forces include illocutory goals (e.g., Assertive, Directive, Declarative, or Questioning) in the speech acts expressed by the interlocutors and their intersubjective interpretation in the context of the activity (e.g., (request for) explanation, elaboration, or clarification, objection, agreement, challenge, etc.). The propositional contents concerned inferences or what the scientists called knowledge construction or transformation. Such methodological tools could yield fine grained descriptions of emergent learning. Schwarz and colleagues showed that emergent learning during interaction cannot be seen as monolithic; they identified what they called *unguided emergent construction in interaction*, and *guided emergent construction in interaction*. The researchers showed that what emerges in interaction uncovers only one aspect of learning. The interlocutory approach concerns then interactional visible learning processes. Other learning processes cannot be discerned during argumentative interaction but by comparing the argumentative interaction with other successive activities. In observing how students who interacted in the emergent construction of a new strategy solved similar tasks individually in successive activities, Schwarz and colleagues identified such as *continuing construction from interaction,* and *retrieved construction from interaction* and traced how these processes succeed or fail in yielding immediate or delayed learning. Such a study suggests the complexity of learning processes, visible and invisible, involved in collective argumentation.

## 5.4 The Need for Studies Integrating Emerging Learning with Learning After Interaction

The study by Schwarz and colleagues not only bridges between two kinds of methods for observing learning but between theoretical tenets. Researchers that study emergent learning in argumentative activities see learning as a highly contextual process emerging from specific social interaction and mediated by special tools; they do not ponder whether the learning as a characteristic of an interaction is foreseen to be capitalized on in later activities. On the other hand, researchers that check products (such as written essays) before and after argumentative activities often suppose that the products represent argumentative reasoning on the issue learned. Two implicit hypotheses underlie this supposition (1) argumentative reasoning about a specific issue is in some way quite stable during a certain period; (2) this reasoning can be measured through an interview or the writing of a composition in which students are invited to react in rubrics that correspond to predefined argumentative categories. We contend that for both camps, there is a need to consider both foci. That is, socio-cultural psychologists should consider how constructs elaborated in collective argumentation activity are capitalized on in successive activities. Also, psychologists adopting a skill acquisition approach should consider and understand the apparent inconsistencies when those skills deploy in social interactions. In their analytic method, Cobb and colleagues (Cobb et al. 2001) apprehend learning in successive activities by observing whether understandings negotiated in specific activities are taken as shared in subsequent ones. But as mentioned before, the argumentative features of talk are unspecified and the role of argumentation in emergent learning in successive activities is thus difficult to observe.

An attempt to trace learning in successive activities, one of them being argumentative, has been recently done by Asterhan and Schwarz (2007): In a pretest-intervention-posttest study, students were asked to solve individually problems on evolutionary theory, then to collaboratively solve similar problems in dyads, and then to solve similar problems individually at two different period of time. Asterhan and Schwarz identified characteristics of dialogue during dyadic interaction and studied relationships between these characteristics and the change in the mental models that appeared between the pre-test and the post-test in individuals. Among the characteristics of the dialogue that predicts conceptual learning, the fact that the dialogue is dialectical – in which different arguments are expressed. Another characteristic concerns the fact that arguments are distributed among discussants and the fact that, in spite of the dialectical character of the dialogue, discussants co-construct the solution.

# 6 Argumentation and Learning in Specific Domains

The findings we brought so far are quite general. However, in several domains, argumentation has been identified with the very language people should use while reasoning. For example, Driver, Newton and Osborne (2000) have claimed that argumentation is the language of Science. Similar claims have been raised in Mathematics and in History first for professional mathematicians and historians, then for students in schools. However, the characteristics of argumentation in which people engage in different domains are quite different. This is because, argumentation, and especially collective argumentation bears domain norms according to which people reason. We describe here theoretical developments and empirical data on learning processes in argumentative activities and subsequent learning gains in four domains, mathematics, science, history, and civic education. The panorama that will stem from research reviews in these domains concerning argumentation and learning will not show a uniform picture, but will uncover potentialities and difficulties that are to some extent domain specific. A caveat before delving into the four reviews: In light of the arousal concerning the role of argumentation in specific domains, a systematic review would have overtaken reasonable limits for the length of the chapter. We preferred then to pick up representative studies rather than being exhaustive.

## *6.1 Argumentation and Learning in Mathematics*

### 6.1.1 Argumentation as a Basic Form of Mathematical Professional Activity

Among all types of scientific activities (in a Vygotskian sense), mathematics has been perhaps the most discussed from an argumentative perspective. In fact, this is not very surprising. In the first chapter of this book, Rigotti and Greco compared demonstration and argumentation through examples in mathematics. And indeed, we all know the terms "demonstration" and "proof" from our experience as pupils attending lessons in mathematics, especially in geometry. Generally mathematics educators contrast between proof and argumentation like Rigotti and Greco: the role of proofs is not to convince but to provide a way to communicate mathematical ideas. Often in mathematical proofs, one single solution is acceptable, and is practically irrefutable. In second half of the twentieth century, mathematicians showed that their professional activity is far from being purely logical but is largely dialectical: in *How to solve it*, Pólyà (1945), showed that mathematical activity is based on heuristics – general strategies for problem solving that may or may not help in specific cases; in *Mathematics and plausible reasoning* (Pólyà 1954), he models mathematical activity under uncertainty. In his influential book *Proofs and refutations*, Lakatos (1976) built on Pólyà's ideas to show that the development of mathematics does not consist (as conventional philosophy of mathematics tells us it does) in the steady accumulation of eternal truths. Mathematics develops, according to Lakatos, in a much more dramatic and exciting way – by a process of conjecture, followed by attempts to "prove" the conjecture (i.e., to reduce it to other conjectures) followed by criticism via attempts to produce counter-examples both to the conjectured theorem and to the various steps in the proof.

### 6.1.2 Formal Proofs and Argumentation in Mathematics and in Mathematics Education

The approaches adopted by Polya and Lakatos to mathematical activity contrast formal proofs as they are recorded in books or journals from the dialectic processes that lead to their elaboration. For mathematicians, it is a way for establishing the validity of ideas in the scientific community. The anecdote about the famous mathematician Paul Deligne who presented the formal proof of a new theorem in a conference in research in mathematics and who asked the audience "Is there somebody that can help me understand now why the theorem is true?". For the mathematician, though, creating mathematics and the inscription of proofs are two distinct but related activities: the mathematician poses problems, analyzes examples, raises conjectures, generates counterexamples and revises conjectures. The elaboration of a proof results from a refinement and validation of ideas that answer the question they posed.

Since mathematical results are presented formally by mathematicians in the form of theorems and proofs, this rigorous practice is mistakenly seen by many as the core of mathematical practice. As stated by Hanna (1989) it was assumed for years that "learning mathematics must involve training in the ability to create this form" (pp. 22–23). Elaborating formal proofs has been a central goal in mathematics education. However, if for mathematicians the creation of mathematics and the inscription of proofs are two related activities, for children they are not. In fact, several leading mathematics educators have stressed the psychological gap that set apart arguing and proving. For example Duval (1993), has shown that although students in schools are accustomed to give reasons and to provide proofs, such actions are generally not relevant (pertinent in his own terms) to them: The explications they give do not convince them of the validity of their arguments. In the same vein, Fischbein and Kedem (1982) asked junior-high school students who demonstrated a geometrical proof correctly whether they are confident of its truth. The students often took the figures they used to demonstrate the proof in order to measure distances with their rulers. Elaborating a proof, then, did not have any role in conviction. In other words, there is a huge gap between arguing and proving in mathematics, especially for young students (similar results in Schoenfeld 1986). Therefore, differently from professional mathematicians, for children, proofs are not products of argumentation; rather the elaboration of proofs and argumentation are two unrelated activities.

### 6.1.3 Suitability of the Toulmin Scheme for Mathematical Activity in Professionals and Students

As shown by Rigotti and Greco in chapter "Argumentation as an Object of Interest and as a Social and Cultural Resource," Toulmin (1958) elaborated a scheme of argumentation in the fifties to distinguish scientific reasoning from formal logic. Several researchers in mathematics education have recently adopted this model to describe mathematical activity, and such an adoption is an important step from a psychological point of view (Aberdein 2006; Hoyles and Kücheman 2002). However, with the Toulmin scheme mathematical activity departs from formal logic but is still a branch of informal logic. In a recent study in which the Toulmin scheme was adopted a priori to describe mathematical activity, Inglis et al. (2007) asked talented post-graduates in mathematics on conjectures in number theory. The researchers showed that, in contrast with the inscription of formal proofs, subjects used modal qualifiers that express doubt, reasonableness or high certainty; they also used inductive warrant-type arguments in addition to their deductive warrant type arguments. Also in contrast with the other researchers in mathematics education who used the Toulmin scheme to describe argumentation Inglis and colleagues (Inglis et al. 2007) included modal qualifiers and rebuttals in what they called a genuine model of mathematics activity. Even in this interesting study, the mapping of the Toulmin scheme upon protocols looks quite imposed rather than adapted to describe reasoning processes in solvers.

The Toulmin scheme seems then too structural to grasp the dynamic, dialectical nature of mathematical activity. This is not surprising: the impressive developments in Argumentative Theory shown by Rigotti and Greco in this work show that this model is gradually abandoned to the advantage of other models.

In mathematics education (as well as in science education) the Toulmin scheme is still in use in spite of the methodological and ontological problems we pointed out. And we think that such an adoption may be good if the Toulmin scheme is used as a tool for educational purposes rather than as a model to describe mathematical activity. Its simplicity can help educators bridging between arguing and proving in classroom activities. When used by the teacher as a cognitive tool, proving and arguing seem in the same spectrum rather than being incommensurable activities. However, so far, in most of the current studies in mathematics classrooms, researchers have neglected the activity of proving to the benefit of the activity of arguing. We present in the next section such studies in which activity in mathematics classrooms is described in argumentative terms, including with the Toulmin scheme.

### 6.1.4 Collective Argumentation in Mathematics Classrooms

Instead of bringing students to reconstruct normative proofs through deductive steps, researchers recognized that the ultimate goal is not necessarily to prove or to demonstrate but to co-construct reasonable arguments in teacher-led discussions. Krummheuer (1995) began studying argumentation for its own sake in mathematics classes, argumentation being defined as "interactions in the observed classroom that have to do with the intentional explication of the reasoning of a solution or after it" (p. 231). Such a focus necessitates the term *collective argumentation* (also Miller 1987). Also, the definition goes astray from the definitions given in chapter "Argumentation as an object of interest and as a social and cultural resource." The retractions, modifications, hesitations, or replacements that occur in classroom discussions cannot be mapped onto any a formal model such as the van Eemeren pragmatic-dialectic model. Kummheuer uses the Toulmin scheme of argumentation as a tool for modeling the explications given during classroom activities. According to Krummheuer, this model "helps to reconstruct the informal logic of an argumentation and the kind of accountability developed for the resolution of a quarrel." Judiciously, Krummheuer notices that "this scheme is not to be understood as a method for identifying the different components of that model in concrete interaction – this needs to be done by a related analysis of interaction. The scheme merely points out the different roles that utterances play in an interaction when reconstructed from a perspective of the emergence of a substantial argument" (p. 240). Krummheuer clearly states here that he does not model argumentation but emerging arguments in classroom interactions. The validity of the structure of such an emerging argument is often problematic since it is reconstructed by the researcher without taking into consideration the concrete interactions into which it deploys.

The role of the Toulmin scheme turned to ancillary in the description of emergent processes by researchers such as Cobb, Yackel, and colleagues (Yackel and Cobb 1996, Cobb et al. 2001). In such studies researchers focus on activities in elementary school in which teachers adopted an inquiry approach. The teachers led discussions to pose problems, then organized students in small groups, then instigated whole-class discussions. The approach to instructional strategies concern both fostering active individual construction and acculturation into the mathematical practices of wider society. The general definition of argumentation given by Krummheuer is taken for granted. Argumentation is the interactive process through which understandings are taken-as-shared and lead to intersubjectivity. These understandings are accompanied by the constitution of socio-mathematical norms that govern the elaboration of beliefs and values. For example, Yackel and Cobb (1996) showed how teachers led discussions in which norms about what are different solutions or sophisticated ones are. In these discussions, students tried to explain to others what seemed not clear for them. By such, the elaboration of socio-mathematical norms in argumentation provided opportunities for learning. Interestingly and almost paradoxically, the concern to be comprehensible by others and to be accepted by them leads to autonomy in active discussants.

Later work by this team of researchers was more specific about the competencies the teacher should deploy to orchestrate the elaboration of desirable socio-mathematical norms and about the role of the design of activities to trigger learning opportunities. Yackel (2002) showed that the teacher needs mathematical knowledge as well as psychological knowledge about the competencies of the students that participate in the discussion. Cobb and colleagues (Cobb et al. 2001) used the term "learning trajectory" to designate the hypotheses designers and researchers have concerning how children would participate in a series of activities. One of the most specific processes that accompany collective argumentation in mathematics concerns the transformation of the object of discussion from material objects to mathematical ones, a component of the process of mathematization (Gravemeijer 1994).

As mentioned above, the direction led by researchers such as Cobb, Yackel, and Krummheuer is based on a very loose definition of argumentation, "the intentional explication of the reasoning of a solution or after it" as stated by Krummheuer. Is it possible to refine the general approach to argumentation adopted, and by such to turn to relevant the models of argumentation proposed in chapter "Argumentation as an object of interest and as a social and cultural resource"? Since "argumentation" is not a condition discussants fulfill or not according to demands, one might wonder about the relevance of ideal models. However, we already mentioned the role of teachers in instilling ground rules (Mercer et al. 1999) or in instigating argumentative moves. These moves or ground rules partly convey models of argumentation. More generally, argumentation theory is relevant to classroom discussion in the design of the environment in which discussions take place. The most immediate design principles concern scripts suggested to students (and to teachers) in discussions such as: "to (help to) accommodate divergent views," "to (help to) give reasons pro and con a certain claim and to give reasons for the decision," "to (help to) convince each other and to reach consensus," etc. Of course, as shown by Atzmon et al. (2006), the interactions that take place as a result of the same scripts for the same activities with different students and/or teachers can be very different from an argumentative point of view. The study of argumentation and learning in mathematics needs then to be more specified to lead to useful distinctions.

One of the main specifications has been the situatedness of argumentation in a field of experience. For example, Duval (1991) listed among others (a) the existence of a "reference corpus" consisting of true statements and reliable arguments – true or reliable because they are institutionalized or can be checked/measured, (b) the existence of doubtful statements. Such specificities have been taken into consideration as part of a design process to lead to learning through participation in argumentation. Douek (1999) used such ideas to describe how fourth grade students learned about inclination and angles through activities on sunshadows in which the students capitalized on real experiences they undertook, and drew then used graphs in discussions in which different arguments were brought forward. In several studies, the design of the tasks possibly leading to argumentation and learning turned to conditions. Such an approach inevitably discerned between types of argumentation and comparison between learning gains for students participating in the different types of argumentation. Schwarz and his colleagues attempted to design situations in which the design concerned the choice of students engaging in small group interaction according to characteristics of their initial cognitions (something similar to Duval's existence of doubtful statements), affordances and constraints of the task, and tools for checking hypotheses (similar to Duval's existence of a "reference corpus"). Concerning initial cognitions, it seems that diversity (in solutions, in mental models, etc.) is preferable. Designing tasks for affording certain cognitive actions, and prohibiting or constraining others is difficult. It demands an epistemological analysis of possible tasks to foresee such affordances and constraints (Schwarz et al. 2000, for learning decimal fractions in dyadic interaction; Schwarz and Linchevski 2007 for learning proportional reasoning in dyadic interactions). However, the types of argumentation in which students engage are diverse. Schwarz and Linchevski (2007) showed that many students engaged in one-sided noncritical argumentation, and that conceptual learning (of proportional reasoning) occurred when students engaged in two-sided dialectical argumentation. The use of technological tools is often necessary to design particularly complex situations. For example, Hadas et al. (2002) designed situations with Dynamic Geometry tools to encourage students to engage in deductive reasoning in geometry in dyadic interaction (without teacher). Also, Hershkowitz and Schwarz (1999) designed an activity to encourage hypothesizing in algebra through the use of graphical calculators in small groups of students. The immediate feedback of technological tools (as well as tools for checking hypotheses in general) proved to be crucial for learning. In all those examples, students engaged in remarkably rich and productive interactions. After many of these activities, a teacher undertook a reflective activity in which dialectical activities were recapitulated to lead to further learning. In summary, although the design of tasks leading to argumentation in mathematics should be meticulous to be productive, this design is possible and is the object of intense efforts in mathematics education.

## *6.2 Argumentation and Learning in Science Education*

Science in schools is commonly considered from a "positivist perspective" as a subject in which there are clear "right answers" and where data lead unequivocally and incontestably to agreed conclusions. This attitude towards science has been rooted in a philosophical-empiricist approach according to which science was considered to be based on empirical processes, where claims to truth are grounded in observation, and where conclusions are unproblematic deductions from such observations. Current research into the activities of scientists, however, points to a different picture: Practices such as assessing alternatives, weighing evidence, interpreting texts, and evaluating the potential viability of scientific claims are all seen as essential components in constructing scientific arguments (Latour and Woolgar 1986). In making scientific claims, theories are open to challenge and progress is made through dispute, conflict, and paradigm change. Science is now viewed as a social process of knowledge construction that involves conjecture, rhetoric, and argument (Taylor 1996). This perspective recognizes that observations are theory-laden (Hanson 1958, Kuhn 1962) and that, therefore, it is not possible to ground claims for truth in observation alone. Claims are seen to be grounded through the generation of arguments that relates the imaginative conjectures of scientists to the evidence available (evidence which itself needs to be open to scrutiny in terms of the way it is framed conceptually and the trust that can be placed in it from the point of view of reliability and validity).

Establishing a knowledge claim in science involves then first the process of establishing what counts as data, through conducting and checking observations and experiments. Then deductions are made from the conjectured theory through reasoning and calculation. The extent to which the data agree or disagree with the prediction then needs to be examined. Rather than a single theory or conjecture to be checked, it is often the case in science that there are two (or more) competing theories. Then the key activity of scientists is evaluating which of these alternatives does, or does not fit with available evidence, and hence, which presents the most convincing explanation for particular phenomena in the world. As Siegel (1989) argued, the central project of science is the search for reliable knowledge, albeit within a limited domain. To achieve this, scientists hold a central core commitment to evidence as the ultimate arbiter between competing theories. Such a commitment, which is basic to science, should therefore be a feature that science education should seek to illuminate strongly.

In addition to the argumentative nature of epistemological aspects of science, over the last few decades there has been an increasing awareness of the social processes that are also involved in the production of scientific knowledge as public knowledge (much more than mathematical knowledge). Science is a social practice and scientific knowledge the product of a community. Of course, this social process involves first the inner circle of other scientists through critical peer review in scientific journals, revision or rejection, and acceptance. However, in presenting and evaluating arguments, scientists are influenced by factors beyond those internal to science, factors such as scientists' social commitments, values, and by the wider culture of ideas and technological capabilities in society at the time (Woolgar 1988).

These different circles of social interaction in which scientists are involved are well illustrated through the exemplary controversy and argument that surrounded the process of establishing whether BSE ("mad cow" disease) can be transmitted to humans. The first level is within the mind of the individual scientist when struggling to design an experiment or to interpret data; second, within research groups where alternative directions for research program are considered in light of the group's theoretical commitments and empirical base; third, within the scientific community at large, through interactions between competing positions at conferences or through journals; and fourth, in the public domain where scientists in a contested field expose their competing theories through the media. Through this discussion of science as the production of socially constructed knowledge, discursive practices play a central role in establishing knowledge claims. Observation and experiment are not the bedrock on which science is built, but rather they are the handmaidens to the rational activity of generating arguments in support of knowledge claims.

But it is on the basis of the strength of the arguments (and their supporting data) that scientists judge competing knowledge claims and work out whether to accept or reject them.

In light of the studies that uncovered what the work of professional scientists consists of, and in light of the societal needs concerning the use scientific knowledge in adulthood, educators have recently expressed the importance of developing scientific literacy (Millar and Osborne 1998, Norris and Phillips 2003). The publication of the American Association for the Advancement of Science volume on enquiry (Minstrell and Van Zee 2000) and other official publications point to a commitment that science should be concerned with more than knowledge of scientific facts. Rather, it should be dedicated to critical reasoning and argumentation (Driver et al. 2000). Science education requires a focus on how evidence is used to construct explanations: beliefs in scientific ideas and theories should be grounded on the examination of data and the generation of warrants; one should understand the criteria used in science to evaluate evidence (Osborne et al. 2004). Comprehending scientific arguments is a crucial part of *scientific literacy* (Osborne et al. 2004). In the same vein, inferring meaning from science texts requires the ability to recognize the standard genres of science, and to evaluate claims and evidence advanced in scientific arguments.

Declaring the necessity to develop scientific literacy, to a large extent enculturation to scientific argumentation and inquiry, is important but faces many difficulties in the science classroom. We review here some of these difficulties. We begin by listing some of the difficulties students have in engaging in argumentation. We then turn to what we think is the main obstacle to enculturation to scientific argumentation-literacy, the current teacher-led classroom talk.

### 6.2.1 Students' Difficulties in Constructing Arguments and in Engaging in Argumentation

The weaknesses reported at the beginning of this chapter in presenting arguments "for and against" about social issues, are more accentuated in science. Drawing on a wide literature relating to science education, Zeidler (1997) identified the following five reasons for fallacious argumentation – essentially the common errors in students' arguments in science and the reasons for them:

1. Problems with validity – students fall into the trap of affirming the consequent and are more likely to affirm a claim if they believe the premises to be true rather than false, despite warrants contrary to their beliefs.
2. A naive conception of argument structure – students tend to have a confirmation bias and select evidence accordingly with little attention paid to disconfirming data.
3. The effects of core beliefs on argumentation – arguments that are consistent with students' beliefs are more convincing than those that are counter to their beliefs. This weakness compromises students' ability to evaluate counterevidence and criticism.
4. Inadequate sampling of evidence – students are not sure what constitutes convincing evidence and tend to jump to conclusions before enough data are

available; their lack of functional understanding of probabilistic information and statistics is also a barrier here.

5. Altering the representation of argument and evidence – students do not necessarily consider only the evidence that is presented to them, but make additional assertions about the context of the problem, or even introduce inferences that go beyond the boundaries of the evidence presented and that introduce bias in the outcome.

And indeed, these considerations have been largely confirmed in an important study by Chinn and Brewer (1998) in which they showed that students have a set of eight responses to anomalous data choosing either: to ignore the data; to reject it outright; to exclude the data by declaring it to be irrelevant to their field of study; to hold the data in abeyance by deciding that there is insufficient data to determine the outcome or too many uncertainties associated with it; to reinterpret the data by arguing that the causal explanation is significantly different from that proffered by the scientist; to modify their theories peripherally by arguing that its effects are minor rather than major; and, finally, to express uncertainty about the data itself. In only 8 of the 168 cases in their study did students modify their views as a consequence of evidence contradictory to their previously held beliefs. Both Zeidler (1997) and Chinn and Brewer (1998) reminded us, in their concluding discussions, that scientific thinking is complex and messy and that the reasoning of scientists themselves is often subject to the same kinds of problems listed above. Inducting students into the norms of scientific argument is therefore an idealistic activity; norms may be accepted by the community of scientists but can be overlooked in practice. Yet, making students aware of both how they, and scientists, respond to contradictory claims will provide important insight into the social processes internal to scientific argument.

### 6.2.2 Difficulties to Sustain Argumentative Talk in Science Classrooms and Programs to Support It

A second obstacle to the enculturation to scientific argumentation concerns talk in classroom. As shown by several scientists that analyzed the language used in science classrooms (Lemke 1990, Mortimer and Scott 2003), their implicit beliefs about science are reflected in their interactions with students in classroom discussions. Teachers commonly share the belief that science is constituted of a body of unequivocal and uncontested knowledge. As a consequence, interactions uncover control over turns, questions that invite short answers that are correct or not. In contrast, apprehending science as not being about absolute and certain knowledge induces more deliberative and dialogic talk in the classroom (Mortimer and Scott 2003). Adopting a new talk, more dialectical and dialogical, in the classroom is then not a matter of adopting a new vocabulary but assimilating new goals, and new epistemic beliefs. The study of talk in science classrooms has then naturally turned to a central issue in two directions. First, researchers are interested in descriptions in order to (a) define the argumentative features of classroom scientific talk, and (b) uncover teachers' and students' beliefs about science. The descriptions are done in natural settings in the sense that the researcher–observer is not interested to engage in interventions of any kind. The second direction concerns quasiexperimental studies in which the teacher opts for a pedagogy that is expected to lead to scientific gains through argumentation. In particular we will review the role and conduct of argument in addressing two emphases in science teaching: developing conceptual understanding and developing investigational capability. We report first on difficulties then, describe representative initiatives to overcome them.

### 6.2.3 Difficulties to Promote Conceptual Learning Through Argumentation in Classrooms

Several studies have shown difficulties the difficulties science teachers have in promoting conceptual learning in classroom discussions. The huge problem to be overcome in these studies is methodological: how to trace the existence or the absence of conceptual learning in classroom discussions. Like in mathematics, some researchers used the Toulmin's model to describe emerging arguments collectively elaborated. For example, Jimenez-Aleixandre and colleagues (Jimenez-Aleixandre et al. 2000) studied the discussions of groups of students about a genetics problem set in a practical "real life" context. With the Toulmin model, they represented arguments as group productions of which they could identify interesting features (e.g., the arguments were very limited in complexity, often warrants were not made explicit, and conceptual confusion affected the quality of the arguments). Jimenez-Alexandre and colleagues also identified aspects of the arguments that could not be represented using Toulmin's scheme; for example, epistemic operations (e.g., causal relations, explanation procedures, analogies, predictions) and the influence of school culture on the arguments produced. What the study did achieve was to make explicit the difficulties students encounter in marshaling evidence, drawing on their conceptual understanding of the topic, and composing arguments in support of scientific knowledge claims. Other studies used theoretical schemes to identify features of the discourse. Some, such as the schemes evolved by Pontecorvo (1987) and Alexopoulou and Driver (1997), are analytical and illustrate the different types of argumentative moves used by students in discussing conceptual problems in science.

### 6.2.4 Difficulties in Developing Investigational Capability Through Argumentation

The process of inquiry is central in scientific activity in which execution and interpretation of experiments should be used to dialectically construct ideas about scientific processes and then to construct models or theories based on those ideas. A number of studies have focused on student argumentation while students solve scientific problems within a conceptual area that requires engagement in laboratory investigations over extended periods of time. For example, Richmond and Shriley (1996) studied the discussions of six groups of four students during the planning, execution, and interpretation of student-designed experiments in a grade 10 science class over a 3-month period. The course was designed around a case study of the nineteenth century cholera epidemic in London, and introduced students to the nature of scientific detective work as well as to basic concepts of cell biology. The goal of this study was to report on how students construct arguments for collecting and using data in a scientifically acceptable form, including their ability to identify a problem, construct a testable hypothesis, design an experiment, collect data, and recognize the implications of the results. The investigators analyzed students' understanding and participation on two dimensions, a conceptual dimension and a social dimension. They considered the interplay between these dimensions in interpreting students' ability to construct arguments as the program of work proceeded. They noted that, at the beginning, students were not able to construct arguments relating to procedural aspects of carrying out their investigations. They had difficulty differentiating between a problem and a hypothesis, understanding the value of controls, and distinguishing between their results and what the observations meant (conclusions). They noted also that, early on in the study, students concentrated on procedural issues with little concern for understanding the conceptual basis of the problem at hand. In general, as a result of the extended program, the investigators reported that levels of student engagement with the problems rose and arguments became more sophisticated. They also noted how the progress of the groups was a product of cognitive and social factors and depended to a great extent on the style of the group leader. This finding serves to emphasize of the importance of social context and the need to develop an understanding of the social rules necessary for "successful" discourse. Druker et al. (1996) also provided an analysis of science students' arguments in the context of solving practical performance tasks. The tasks used in their study involved electrical "mystery boxes." Students cooperated in pairs to work out, through empirical tests, what the electrical components in a set of boxes might be. The students' actions and discussion were documented and analyzed using Toulmin's argument framework and as a result a range of types of errors in students' arguments were identified.

The overall picture of the study of classroom talk is that high quality argumentation in school classroom (e.g., the use of valid argument) does not come naturally and is acquired through practice. The implication for science education is that argumentation is a form of discourse that needs to be explicitly taught (Hogan and Maglienti 2001; Kuhn 2001, Simon et al. 2006, Zohar and Nemet 2002). The issue is then to find ways in which teachers can appropriate the discourse of argumentation and whether changes occur in the nature of teachers' classroom interactions.

### 6.2.5 Intervention Studies to Improve the Quality of Argumentation in Science Classrooms

Intuitively, instilling the discourse of argumentation in science classes may seem a quite simple matter limited to the enactment of certain teacher actions. For example teachers may think of presenting different points of view on the same issue by posing tasks within an oppositional framework (e.g., debates or arguments for or against in a discussion group). Boulter and Gilbert (1995), however, argued that this oppositional structure, and the polarized language that ensues, can be a problem. Furthermore, they suggested that "an inclusive rather than oppositional language has more connection with personal experience." In fact, this example suggests that instilling the discourse of argumentation in science classes is not simply a matter of learning to apply a list of recipes for teaching action.

In some studies, researchers proposed to the teacher to impose rules of scientific discourse and inquiry. For example, Herrenkohl and Guerra (1995) examined an intervention study designed to improve the quality of argumentation employed by students when engaged in investigations. Two classes of fourth grade students from one school were involved in the study that was conducted over a period of 12 teaching days while the students were engaged with a hands-on, inquiry based curriculum unit on "structure and balance." The purpose of the intervention was to engage students in "performances of understanding" in science. To promote this, in the case of both classes, the "rules" of scientific discourse and inquiry were made explicit to the children. Three discourse practices were focused on: monitoring comprehension; coordinating theories (and predictions) with evidence; and challenging others' perspectives and claims. In one of the classes the teacher explained these practices and reminded the children about them each day. The teacher did the same in the second class, but in addition, the children were assigned sociocognitive roles designed to help them monitor each others' reports as they conducted their work. The roles were: checking reports for statements of predictions and theory; checking reports for a clear summary of results; and checking that theory is supported by evidence in reports and, if not, generating alternative accounts. Children took turns in practicing these roles. The oral reports given to the class by the children were recorded and the discourse moves were analyzed. There was clear evidence that, in the class in which the children were assigned roles, the reports from the children included a larger number of the target discourse moves than for the other class. Thus, these findings suggest that, not only is it important to inform students of the norms of scientific argument, but, if students are to assimilate these norms, they also need the experience of rehearsing them for themselves.

Studies like those by Herrenkohl and Guerra show that instilling scientific rules of discourse is possible, but these studies centered on the learners only. They conceal the huge effort needed from teachers to orchestrate collective argumentation in class discussions. Several in-service teachers programs have been implemented for this purpose. For example Simon et al. (2006) have trained 12 teachers in a 1-year long program to teach argumentation. The researchers used the Toulmin model of argumentation not only as a tool for analyzing lessons but as a tool for training the teachers to engage in argumentation in their classes: it appears that the simplicity of this tool that makes salient argumentative components (claims, data, warrants, backing, rebuttal, etc.) helps teachers appropriating argumentative norms in discussions. The program not only enables teachers to use the language of argumentation but to get immersed in inquiry, questioning, experimentation and to engage in concrete teaching tasks in which they capitalize on their experience with students. Learning to teach argumentation is a very long lasting process which took, in the case of Simon and her colleagues one full year. The good news are that the program was successful not only concerning the quality of arguments co-constructed in classes but concerning the quality of argumentation as it appeared in moves such as justifying with evidence, or counter-arguing: The teachers in the second year of their teaching were better than in the first year according to both argument structure and argumentation.

### 6.2.6 Environments for Promoting Argumentation

In addition to in-service teachers programs, researchers and designers have developed several technology-based environments for sustaining argumentation in science. The reason for these huge development efforts in Science education is the recognition of the complexity of processes involved in instilling a new scientific literacy that integrates investigational and argumentative practices. In chapter "Argumentative Design," some of these environments are described, some of the ones that focus on the argumentative part of scientific activity (e.g., the Belvedere system). Several researchers have proposed environments that integrate facilities for inquiry as well as for argumentation. As announced at the beginning of this section, our review is far from exhaustive and is rather representative.

As an example among many other environments for promoting argumentation in science, a group of researchers participated in the EC-funded ESCALATE project (http://escalate.org.il/engsite/home/default.asp) in which cases integrating argumentation and enquiry-based strategies were integrated in two distinct environments. For argumentation, students used Digalo, a graphical tool with which the argumentative moves of synchronous discussions are gradually represented and can be reflected on. e-discussions with Digalo occurred in small groups of 2–5 students; in some groups, the teacher intervened (the teacher could not intervene in more than two groups in a classroom e-discussion). For the enhancing of enquiry, "Microworlds" were designed and tailored for specific uses, and allowed students to change, for example, the initial conditions of a physical phenomenon, isolate a specific factor and see how it influences a certain physical procedure, etc. In that sense, students experimented to define the physical laws that dominate phenomena. They could use trial and error methods to examine "what will happen if…"situations, and they can transform the environment "so that … will happen," etc. In this way students could test their hypotheses and discuss the most viable. The description of the implementation of the different cases in five different countries pointed at several generalizable phenomena (1) The very nonconformist kind of environments and pedagogical approach demand to negotiate with teachers, principals, educators the kinds of cases to be implemented; the negotiations were far from being trivial processes; the kinds of solutions for implementation highly depended on the microculture of the class, and the institutions. (2) The teachers participated in several workshops or meetings in they were immersed in the new literacy of science. (3) After the negotiations, the implementation of the cases led to important conceptual gains. (4) In spite of the preparation of the teachers, they had often very hard time to intervene, especially in small group e-discussions.

This short review points at the potential of environments and the capability of teachers to lead a reform in science education based on a new literacy. However, this potential demands huge investments in teacher training, in design and in software development.

## *6.3 Learning History Through Argumentative Activities*

While in Science and in Mathematics, educators have difficult time to design argumentative activities in which students engage in productive discussions, the situation in history should have been much easier: among school activities, discussions on historical issues can be the closest to discussions in natural settings. This is only a potentiality, though. The juxtaposition of history education and argumentation reflects a deep change in history education in which many educators hesitate to engage: the initial goal of history education (in the nineteenth century) was to instill authoritatively collective memory and social identity (Ferro 1984; Funkenstein 1989). The introduction of argumentative activities in history classrooms gives legitimacy to critical analysis of official narratives and to the acquisition of alternative perspectives. From a psychological point of view, some educators) have suggested that an argumentative approach risks having an unsettling effect eroding students' values and identity (Naveh and Yogev 2002). Proponents of the reform have suggested that encounter with diverse historical sources and group discussions transform the collective memory narrative from a self evident truth into a freely taken personal perspective. As Baker (2003) claims, argumentative activity turns accounts into stands held by protagonists in historical action and participants in historiographical debate. Societal and ideological changes concerning autonomy and authority in modern society have led educationalists to favor a critical approach in history education (Nash and Dunn 1995). They developed new kinds of activities such as evaluation of historical sources, discussion of multiple texts, or argumentative writing (Hynd 1999). By doing so, they bring the historian's craft to the school, a craft in which most of the practices are argumentative (Wineburg 1994).

Empirical findings on the effects of this reform on historical reasoning are still rare but encouraging. For example, Perfetti et al. (1994) showed that historical problem solving argumentative activity may influence narrative, attitudinal, and argumentative characteristics of student's writing: in a well designed experiment based on the critical reading of conflicting sources, they showed that opinions turned to more two sided. They also pointed to relations between changes in empathy and in argumentative level of text writing and the use of information from historical sources – a clear indicator of historical learning.

Goldberg et al. (2008) undertook another study based on argumentative activities. They obtained similar results concerning the improvement of argumentative writing. A major difference between the two studies is that in the Perfetti et al. study, the issue was quite neutral (the history of Panama) while Goldberg and his colleagues designed a study in which the researchers focused on the effect of the vitality of historical issues in collective memory on students' history learning processes and products. Forty 12th grade students of different ethnic background participated in two historical problem-solving learning tasks. The historical issues were found to differ in their vitality in collective memory as signified by students' consensus, certainty, and reference to the present. These differences defined vitality as expressed in living and dormant collective memories. Findings showed effects of vitality on narrative and argumentative change, and on the relation of historical source evaluation with narrative change. An interaction was found between issue vitality and ethnicity in the source evaluation: more vital collective memory narratives were more resistant to change and more prone to ethnic identity bias. In the case of living collective memory, two groups representing two different narratives were involved in argumentative activities. Goldberg and his colleagues showed that when the debate is in the context of inter-group relations it heightens awareness of in-group membership, "making social categories salient." Thus, on the one hand the preconceived collective narrative of the past is more open to change, and on the other hand it arouses social identity motivating its change. Argumentative strategies and historical sources serve as resources for social identity needs.

The fact argumentative improvement relates both to stability and change of attitude shows that historical argumentative activity does not simply free learners from the influences of their subjective preconceptions into the realm of unbiased critical thinking. The motor and motivator of argumentative change is still the individual's fundamental attitudes and needs, often stemming from social identity. Argumentative activity and the critical encounter with diverse historical sources somewhat loosens the hold of collective memory and widens the scope of narrative choices for the individual.

## *6.4 Argumentation and Learning in Civic Education*

Although we showed that argumentative practices are inherent in mathematicians', scientists', or historians' crafts, and should be adopted in schools, the connections between civic education and argumentation seem to be even more natural. First, democratic citizenship, is in itself of argumentative nature: political engagement – the willingness and the capability of citizens to participate effectively in self-rule, and an understanding and commitment to the fundamental processes in democracy, demand from the citizen to know to express opinions (e.g., in petitions), to participate to debates, to bargain, or to make compromises. Second, in civic education – the domain aimed at educating to democratic citizenship, argumentation seems a priori a powerful tool for learning to be a democratic citizen. However, we will see that systematic research on learning processes in civic education has not been initiated yet. Rather, studies report on the success of civic education programs by measuring relevant skills before and after the implementation of the program.

But what are these skills? The National Standards for Civics and Government and the Civics Framework for the 1998 National Assessment of Educational progress

(NAEP) recognize the centrality of critical thinking: identifying and describing, explaining, and analyzing, and evaluating, taking, and defending positions on public issues. A second category of skills essential for democratic citizens are those of participation or civic engagement, what is also called participatory skills. The National Standards identify participatory skills as interacting, monitoring, and influencing. To interact is to be responsive to one's fellow citizens: to question, answer and deliberate with civility, build coalitions and manage conflict in a fair and peaceful manner. Monitoring politics and government refers to the skills citizens need to track the handling of issues by the political process and by the government, and to the exercising of "watchdog" functions. Finally, the participatory skill of influencing refers to the capacity to affect the processes of politics and governance, both the formal and informal processes. Argumentation stands of course in the middle of critical thinking and participatory skills. The kinds of argumentative talks are highly diverse: disputes (to win), conflict resolution (to accommodate divergent views), critical discussions (to understand a compound issue), etc.

Numerous, and varied programs in civic education have been implemented in the world. The United States Agency for International Development (USAID) has undertaken a very large study to measure the impact of such programs all around the world. The most important finding of this study is that if civic education programs implement participatory methods, focus on issues that have direct relevance to participants' daily life they can have positive impact on democratic behaviors and attitudes. But many programs do not meet such criteria. We would suggest that the success of a program relies on the diversity of argumentative activities implemented in the program. Our suggestion does not rely on research: research on civic education focuses on changes in beliefs and attitudes only and not on learning processes.

In spite of the scarcity of research on civic education, the suggestion we just proposed seems reasonable in light of the success of one of these programs, Project Citizen, that has been developed by the Center for Civic Education in more than 30 countries in the world. Project Citizen involves early adolescents in the identification and investigation of important public issues in their own communities. They work cooperatively to propose, justify, and advocate a public policy which will address a particular community need they have identified. This program led to extreme change in students' beliefs about their critical thinking and participatory skills. However, typically for a program in civic education, the measure of progress concerned beliefs and attitudes, and did not concern skills. But does the change concern really skills? Especially when students participate in activities in which the realization of goals such as wining a debate is at stake? We doubt it. Rather, we suggest that reports on shift in practices are more instructive than reports on beliefs or on the acquisition of skills. Practices on which shifts may be traced are political debating, bargaining, and compromising. In addition to practices, several political scientists have proposed that the adoption of civic dispositions rather than civic skills is at focus in programs in civic education. Galston (1995) for example, identified "a commitment to resolve disputes through open discussion … and to engage in public discourse". This disposition includes "a willingness to listen seriously to a range of views and the willingness to set forth one's own views intelligibly and candidly as the bases of a politics of persuasion rather than manipulation or coercion". The second disposition listed by Galston makes clear why what is needed for him in civic education is not the acquisition of skills: "To narrow the gap between principles and practices in liberal society…For citizens it can mean either a public appeal or quiet acts that reduce the reach of hypocrisy in one's immediate community". These dispositions add up to a long list of should be done recommendations to foster civic education. These dispositions are understood to stem from frequent classrooms discussions that progressively enable their emergence.

In summary, the enactment of varied argumentative activities seems to be much more essential in civic education than in mathematics, science, or even in history. However, systematic research on the implementation of such argumentative practices in civic education has not been done yet. Such necessary research should put to the fore the essentiality of argumentative practices in education to turn people to better citizens in their society.

Interestingly, like for mathematics, science, and history, the progressive adoption of argumentative practices in civic education points at a growing sensitivity to students' motivation and beliefs and to the role the domain – here democratic citizenship, for the sake of society.

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