THE "POWER" OF TEXT PRODUCTION ACTIVITY IN COLLABORATIVE MODELING : NINE RECOMMENDATIONS TO MAKE A COMPUTER SUPPORTED SITUATION WORK

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ABSTRACT

Language is not a direct translation of a speaker's or writer's knowledge or intentions. Various complex processes and strategies are involved in serving the needs of the audience: planning the message, describing some features of a model and not others, organizing an argument, adapting to the knowledge of the reader, meeting linguistic constraints, etc. As a consequence, when communicating about a model, or about knowledge, there is a complex interaction between knowledge and language. In this contribution, we address the question of the role of language in modeling, in the specific case of collaboration over a distance, via electronic exchange of written textual information. What are the problems/dimensions a language user has to deal with when communicating a (mental) model? What is the relationship between the nature of the knowledge to be communicated and linguistic production? What is the relationship between representations and produced text? In what sense can interactive learning systems serve as mediators or as obstacles to these processes?

1. INTRODUCTION

Modeling tasks have as a goal for a student to construct an explicit and runnable model of a domain. To obtain the data needed to construct the model, experimentation may be required. Modeling tasks carried out in collaboration seem to require communication and negotiation at the conceptual level (making explicit and elaborating concepts used), the level of problem solving (goal setting, planning, search for information, steps to take, partial solutions to evaluate), and the level of the collaboration itself (regulation and co-ordination). In this framework, partners build models of one another, because they have to construct and negotiate a shared task-representation (Erkens and Andriessen, 1994). This is a problem as well as an opportunity for learning.

The exchange of information in such tasks can be mediated by computer systems that transmit and manage communicative actions. The computer interface affords tools and utilities for the exchange of

information (chat, email) as well as for problem solving (calculators, simulations, etc.). The study of such affordances is important for understanding facilitation of learning in interactive situations.

The collaborative situation that we describe here permits protagonists engaged in a modeling task to exchange information via a network. In this situation (short) texts (messages) are produced with different functions, depending on the subtask that is being carried out. This communicative situation involves, for a given individual, alternating between message comprehension and production phases; learning may result from both the production and the comprehension of text, or from a series of texts. Messages concern the problem at stake, the problem situation, procedures and strategies, partial solutions and goals, conceptual issues, and the collaboration process itself.

The purpose of this chapter is a double one. In the first place we aim to more precisely define the mechanisms and constraints involved in this passing on of information by participants during Computer Supported Collaborative Learning (CSCL), from the viewpoint of psycholinguistic models of written language comprehension and production. In the second place, and as a result of this psycholinguistic analysis, we propose recommendations for improving computer support for modeling activities, by operating on parameters of the exchange of written messages during this process. This is not an empirical paper, but it is meant to serve as the starting point of issues to research.

Our exploration is based on the assumption that the communication of knowledge, or more precisely, the activity of passing on knowledge as textual information (i.e.: the production of a structured message, comprising at least a written phrase), in an interactive situation, could by itself be important for learning. In part 2 of this chapter we discuss how such learning can be explained. At least, learning by using language for communicating knowledge has two sources: comprehending other people's messages and producing ones own messages. We will briefly discuss the current views held about the mechanisms involved in comprehending written information. More important for this chapter, we subsequently proceed to discussing the *epistemic effect* of text production, that is, the hypothesis that the activity of producing written code can bring about learning by the producer of the message. This 'auto acquisition' of knowledge through writing is a consequence of using *written* code, and more specifically, the result of the interaction between knowledge and the linguistic processing involved during writing. We discuss two possible

explanations of this phenomenon. The first explanation (the *classical* position) supposes that it is the act of writing for somebody, and the involvement in meeting specific communicative constraints, which modifies domain knowledge. The second explanation (the *romantic* position) supposes that, in contrast, free (written) expression of thought on the basis of some theme, *without* the requirement to meet constraints such as dealing with audience, permits the writer to constitute new domain knowledge.

In the third and final part of this chapter we draw some consequences of this line of thinking to computer-mediated discussion. What general interface characteristics would be required for full text power to be used for conceptual reasoning and problem solving in computer supported collaborative learning situations (CSCL)? This chapter should be taken as an attempt to bring CSCL design experience to bear on issues about how writing affects learning.

2. THE ROLE OF WRITTEN MESSAGES IN THE COLLABORATIVE MODELING SITUATION

2.1 The notion of collaborative modeling

We define a collaborative learning situation as one in which two or more students work together to fulfill an assigned task within a particular domain of learning to achieve a joint product. In ideal co-operation, the collaborating partners (two, at least) must have a common interest in solving the problem at hand. In addition, we suppose that in a learning situation, knowledge of either participant is insufficient to solve the problem. Furthermore, participants should be mutually dependent on the information and co-operation of the other to reach their (shared) goals. Only when the participants have abilities or information that are complementary, can co-operation be fruitful and will it be looked for (Erkens, 1998). As a result, not only may participants share some of each other's knowledge, but also, in principle, new knowledge may be constructed during the activities.

We consider modeling as a problem-solving task, during which (incomplete) knowledge of concepts (called declarative or semantic knowledge) and knowledge for the application of concepts (often called procedural knowledge) are needed for solving the problem. In most educational situations during

which modeling tasks are employed, the attainment of more of such knowledge is the main goal. In the collaborative situation the learning goal is supposed to be served by individuals communicating information. For this communication both protagonists apply linguistic knowledge for production and decoding of written messages, and pragmatic knowledge, seen here as knowledge of how to adapt the content and the form of a message to the goals of the situation and its participants. For the regulation of activities, we suppose the existence of metacognitive knowledge, which allows the protagonists to evaluate the implications of different knowledge activities.

Problem solving in individual modeling tasks entails dynamic application of domain knowledge, based on the protagonists' knowledge. Learning is the result of active exploration, applying this knowledge to the problem solving process. Consequently, learning to model is based on appropriate experiences and reflections by the learner. The learning environment should be specifically tailored to meet these ends. The learner should not only be supported during problem solving, but also, and more importantly, supported in engaging in abstract reflections leading to (declarative) knowledge that would permit new problems to be solved independently of the supporting environment (Salomon, 1993). Many researchers claim this requires extensive use of specific forms of language (Ohlsson, 1993; Andriessen & Sandberg, 1999; Baker, 1999).

A modeling task carried out as joint problem solving with exchange of written messages represents a rich environment. Knowledge acquisition does not merely involve learning by doing, as in the individual case, on, since at least two other modes of learning are possible: (1) learning by observation of the partner's actions and (2) learning by understanding and producing language through which information is exchanged in relation to the problem solving situation, between (two) protagonists. Many functions may be served by using language; as stated above, we focus on the conceptual aspects - that is language referring to knowledge of the learning domain.

Concerning (2), learning by using language, comprehension by one protagonist (the receiver) of messages written by another protagonist (the sender) is one of the key activities of learning. As we will see, comprehension activities can take place at many levels of depth and can be very different with respect to their focus of attention, depending on characteristics of the learner, the learning situation and the type of instruction. Many studies into collaborative learning address these conditions for learning (e.g. O'Donnell

and King, 1999). In such studies, the main question often is how instruction can facilitate collaborative learning and to which extent. In other words, receivers' learning is studied in terms of how messages by senders do or do not facilitate learning.

Nevertheless, the comprehension by a protagonist of a message produced by another participant is not the only vector to knowledge acquisition. The companion track of the communication route, that is, the production of the message itself, may also imply or even require, on the part of the writer, a restructuring of his own knowledge. So, even if the activities of language comprehension and production are subordinated to reasoning and problem solving processes (e.g. Voss, Wiley and Sandak, 1999), we would like to argue that especially language production activities are not neutral with respect to knowledge construction. The fact that you have to elaborate a message is not a simple translation activity. In point of fact, there is a complex interaction between the process of written language production and the knowledge that is mediated. On the one hand, the nature of the domain knowledge involved may affect the way in which the domain is expressed: what can be thought of clearly is expressed more easily. A domain expert constructs elaborated texts and well-structured written messages with more ease than novices do (Kellogg, 1987; Caccamise, 1987; Alamargot, 1997, etc.). On the other hand, the fact that domain knowledge is expressed, particularly as written text, leads to modification and even growth of that knowledge (Eigler, Jechle, Merziger and Winter, 1991; Galbraith, 1996, 1999; Alamargot, Favart and Galbraith, 2000). Seen in this way, the production activity contributes to knowledge construction, in the sense of strengthening existing domain knowledge as well as allowing the generation of new domain knowledge.

In fact, the main point we are trying to make has also been stated elsewhere, by Schwartz (1999): "Language and linguistic representations play a particular role in generating new knowledge and may be a primary mediator of learning effects, whether alone or in combination" (Schwartz, 1999; p. 211). Schwartz discusses the process of learning from texts. He starts with the observation that the presence of a physical object does not ensure a common ground between two people who both have access to that object. Language may help to construct this common ground, but common meaning and learning between individuals is not assured either. The point is that (oral) language can serve as a construction tool, perhaps up to the point of what is (socially) accepted as common understanding. Schwartz specifically discusses the

power of language with regards to structure, more precisely, as a mediator for restructuring understanding. For example, language may help resolve an ambiguity simply by giving something a name, or calling for an abstract concept that captures or clarifies the meaning of several lower level ones. For social reasons members of a group move to conceptually safe places to communicate, where interpretation differences do not tend to get in the way. Because of this, group communication tends to move towards abstraction and structure, and this restructuring may be an important effect of language use during collaboration. This helps students to discover specific features that allow differentiating chunks or classes of concepts, much as a botanist can distinguish sub-species of a given flower. In his conception, it is the combination of language comprehension and production activity that fosters learning.

Given the important role of language in learning, in the next sections, we discuss the role of the comprehension and production of written language in problem solving. Note that these days, electronic communication essentially is written communication, and even if in the near future audio would become commonplace in such cases, we would still be interested in the specific role of the written communication mode. Our final constraint is that we primarily consider the case of synchronous communication, that is, protagonists act together during the same time slot to solve the problem.

2.2 Comprehending written messages as a tool for modeling activities

The processes of language comprehension involve the modification (adaptation) of a protagonists' model of the situation, based on external information and feedback from the partner. Partners may jointly explore a problem space, but may also instruct one another during the process. Furthermore, there may be modeling involved in collaborative problem solving, in the sense that partners may capture and copy ways of communication and problem solving from the other.

Within the cognitive perspective we are taking here, learning is viewed as updating of memory representations by linking new information to information already in memory. If this leads protagonists to apply information to accomplish new things, or to do something in a different way, learning may be said to

be successful. The issue of the extent to which a teacher, a learner, or a context decides what is successful or not, is left open here (for a discussion: Andriessen & Sandberg, 1999).

Memory for a particular concept is a function of its individual properties as well as of its relations to other concepts. Current cognitive views on discourse understanding (e.g. Fletcher, 1994, for a review) still rely on the distinction made by van Dijk and Kintsch (1983) between three levels of mental representations. The most superficial and short-lived of these represents the surface form of the discourse. The meaning of the discourse is represented as an interconnected network of ideas called the propositional text base, constructed on the basis of syntactic, semantic and pragmatic interpretation of the sequence of words. The most enduring level of representation is referred to as the situation model. This would be similar to the representation that would result from directly experiencing the situation that the discourse describes (Fletcher, 1994). It involves an 'integrated structure of episodic information, collecting previous episodic information about some situation as well as instantiated general information from semantic memory' (van Dijk and Kintsch, 1983). Situation models are dynamic and are updated by inferential processes. Conversely, the nature of inferences that are made during interpretation is based on the already constructed situation model. The ease with which a model is constructed depends, among other things, on the coherence of the information, that is, for example, the consistency of the information and of co-references between information units in a text, all of which supports inference making.

Concerning the nature and amount of inferential processing during comprehension it seems that this depends on several characteristics of task and comprehender. One of the consequences is that for some researchers (for a discussion: Garrod and Sanford, 1999) it seems impossible to describe one unique interpretation of the information in a text, because mental representations are the result of an interaction between text and reader. Another consequence is that inferences are an essential aspect of comprehension, because without inferences, no mental models will be constructed. Minimal viewpoints on inferencing stress the economic tendency of readers to infer as little as possible, only to comprehend what is necessary (McKoon and Ratcliff, 1992). Comprehension is seen as an incremental process, in which much processing is shallow, based on perceived semantic relatedness of words in a sentence (van Oostendorp, 1994), or on activated scenarios of real-world knowledge (Garrod and Sanford, 1999). A related proposal by van Dijk

(1999) involves the activation of event models, that is, models that represent the subjective interpretation of discourse or text, in which only relevant properties of a situation are represented. The extent to which such properties are shared between participants in a situation is part of the common ground participants develop and extend during joint discursive and other action (Clark & Brennan, 1991). Van Dijk (1999, p. 124) supposes that these subjective representations exert overall and local control over all processes of discourse comprehension and production. This subjective component seems to be very important, and it appears that the effects of collaboration on comprehension depend to a large extent on subjective factors, that affect the depth to which a student is engaged in comprehension activities.

Comprehension seen as a learning process is quite sensitive to individual and situational differences and types of knowledge. As a consequence, models of text comprehension do not explain learning. The factors that determine the degree of activation of concepts during comprehension, the amount of related concepts that are activated during reading, and what is learned and to what degree as a result, are to be found outside the model itself, in the attitudes of readers toward the learning situation, and in other characteristics of readers, situations and instructions (e.g. van den Broek, Young, Tzeng and Linderholm, 1999). What is learned is determined to a degree by what is useful for the reader, for example for maintaining comprehension to a degree sufficient to continue a dialogue.

With respect to learning, a minimalist option for comprehension activities is undesirable, as learning requires all kinds of constructive processing activities by the learner, not just the minimal ones (e.g. Goldman, 1996). In addition, it seems not easy to decide what is useful or necessary, neither by a learner (what criterion, where does it come from?), nor by a teacher, because it requires a teacher to decide what is necessary for the learner, leading to problems of responsibility and authenticity (Petraglia, 1998), and, of course, of student modeling.

In addition, it seems that so far nobody has come up with a clear conception about what it means to understand something, nor of the notion of depth of understanding. Here, we suppose that semantic understanding is something gradual, which cannot be pinpointed to specific concepts being understood, but more to a sense of easy recognition of something, feeling more familiar, being able to undertake some more or less intelligent action with it, etc. (Bereiter, in press). Understanding is also much related to the situation,

that is, the collaborators local and overall goals (Baker, Hansen, Joiner and Traum, 1999). It is in this sense too, that groups can understand. This may also be a reason why we often do not observe much explicit understanding, or signs of knowledge transformation in electronic discussion groups (compare Veerman, 2000; p. 159).

To conclude, while it seems obvious that the activity of language *comprehension* in individual as well as in synchronous collaborative situations, can lead to learning, whatever its nature, a whole series of conditions have to be met before deep learning can be realized. We will now turn to the case of (written) language *production*, where we may end up with quite a different conclusion.

2.3 Written message production as a tool for modeling activities

In this section our aim is to discuss the characteristics and activities of the message producer. This approach is rather unusual, as it supposes that the act of producing a written message for someone else is by itself a situation of implicit (self-) learning. This learning situation rests on the interaction between domain knowledge and the activity of language production, which allows the mediation of this knowledge. In the next section, we would like to briefly discuss the principal dimensions of the activity of text composition (section 2.3.1.). After this discussion, we try to elaborate on the nature of the interaction between domain knowledge and language production. This interaction will be discussed from two sides: (1) the effect of domain knowledge on the production of a message (section 2.3.2.), as well as (2) the effect of the production of a message on domain knowledge (section 2.3.3.).

2.3.1. Knowledge areas and processes involves in text composition

If domain knowledge (as in Long Term memory, in a situation model, a mental model or an event model) is considered as a source for text production and elaboration, producing a text supposes at least three other kinds of knowledge: (1) linguistic knowledge: for expressing this knowledge; (2) pragmatic knowledge: allowing a writer to elaborate a representation of a potential and missing reader and (3) procedural knowledge: to trigger and to manage processes applied on the three other kinds of knowledge.

More than twenty years ago, Hayes and Flower (1980) proposed a first model (one probably should use the term "blue print") about the nature and the architecture of writing processes and the implied representations underlying text writing activity. They distinguished three major processes, corresponding to the three main stages of writing: Planning, Translating and Reviewing. The dynamics of the activity are postulated as sequential, with possible recursion, according to the considered phase of production (implying a process called Monitor). Within this model, Planning serves to establish an outline of the content of the text to be written (things to say, to whom, in what order, how), which implies retrieving content from memory (Generating), and Organizing this content in function of the instruction and the writer's communicative and processing goals (Goal setting). The Translating process serves to semantically develop each part of the plan and translation into linguistically elaborated sentences. Reviewing, finally, implies rereading what has been written and eventually modifying (Editing) the text content and/or form.

According to this 'classic' model, the production of a text is described as a progressive transformation of a multidimensional reserve of domain knowledge into a linear linguistic trace. Obviously, many factors affect this transformation and its efficiency, making it important to be able to handle (in working memory) many constraints and processes at the same time (Cf. Flower and Hayes, 1980; Kellogg, 1996), and evoking questions about the effects on the process of the amount and quality of different types of available knowledge. With respect to this last point, a crucial part of written language production is played by the writer's level of expertise of the domain, facilitating not only the production of well-structured text content, but also the planning process as a whole.

2.3.2. The effect of domain expertise on text production: "ce qui se conçoit bien s'énonce clairement"

Beginners and experts do not only differ in the quantity of prior knowledge that they possess, but also in the organization of that knowledge. All knowledge acquisition, and hence the development of expertise in a given domain, requires and depends on a reorganization (restructuring) of existing knowledge, represented (e.g. in Long Term Memory), or activated (e.g. in Working Memory), relevant to the domain in question. For example, ADDINEgan and Schwartz (1979)ADDIN compared the recall of diagrams of electronic circuits by novices and experts in the domain. They showed that the content of the

products of experts was much more structured, at the semantic level, than that of novices. This phenomenon seemed to be related to a better structure or organization of this knowledge in memory by the experts.

The effect of the development of expertise, which has been examined across a great number of tasks as different as chess playing (ADDINChase and Simon, 1973; De Groot, 1965)ADDIN, playing Go (ADDINReitman, 1976)ADDIN, or computer programming (ADDINMc Keithen, Reitman, Rueter and Hirtle, 1981)ADDIN, involves the creation of a great number of semantic relations or associations (chunks - units of knowledge at some higher level of conceptual abstraction - ADDINMiller, 1956; Simon, 1974ADDIN), between the different units of knowledge that characterize the domain in question. The development of expertise can essentially be described in terms of a growth of the number and size of "chunks", which allows an expert to simultaneously access and process a greater number of information units united by a similar conceptual category, and even to create new conceptual categories. This development does not only allow the activation of a very elaborated representation in Working Memory, but also, according to ADDINChi, Glaser and Farr (1988)ADDIN, the establishment in Long Term Memory of more and more hierarchically structured knowledge units. In this light, Caillies, Denhiere and Jhean-Larose (1999) suggest that the knowledge of advanced subjects in a domain is organized in a hierarchical goal-subgoal structure, whereas that of intermediates and beginners is organized in a temporocausal chain. Hence, to be an expert in (or being more familiar with) a domain, supposes the existence of a knowledge representation that is denser, in terms of the number of knowledge units, but also contains a greater number of semantic relations between those knowledge units. The hierarchic organization of the units supposes that the lower level units are attached to higher level units, consisting of groups of related concepts that form cohorts of semantic categories ADDIN(Rosch, 1973; Rosch, Gray, Johnson and Boyes-Braem, 1976; Rosch and Mervis, 1975)ADDIN.

The question then is to explain to what extent richer and denser domain knowledge, which characterizes expertise, can modify the way in which an individual expresses content through language, or more exactly, by means of producing written language. Two complementary processes will be considered:

the effect of qualitatively structuring text content, and that of facilitating processes subordinated to this structuring process.

Structure of knowledge and structuring of text content

According to Caccamise (1987), the structure of domain knowledge is more hierarchically organized when the domain is more familiar to the writer (as seen above), and this has two types of effects on the activity of writing a text: the products assembled in Working Memory will be (1) more extended, because of the greater number of associations between chunks, and (2) already organized in terms of semantic or conceptual relationships. These two characteristics considerably limit the necessity for additional writing processes of organizing knowledge and they permit to generate text content that is already highly structured and hierarchically organized. From this perspective, Caccamise (1987) had 16 psychology students compose texts on the basis of different topics, manipulating the familiarity and generality of the topics. To find an effect of the topic manipulation on the textual level and the underlying processes, Caccamise analyzed in detail the hierarchical organization of the texts produced in each condition. First, the text content was cut into idea units, and their organization was analyzed in terms of chunks (grouping of units of several related ideas). Chunks could be organized in terms of different hierarchical levels, and could eventually be clustered (groups of related chunks). By listing text content in terms of the number of idea units, the number of chunks, the number of idea units per chunk, the hierarchical level of chunks, the number of clusters, etc., the author was able to show that in the case of greater domain expertise, text content can be characterized not only in terms of a greater number of idea units, but also in terms of a stronger hierarchical organization. This organization displayed a greater number of chunks and clusters, related in terms of superordination and subordination. This facilitation was to a great extent due to the structural characteristics of the domain knowledge that could directly furnish the organization of semantic relationships used during text planning and content elaborationADDIN (Schneider, Korkel and Weinert, 1989). More precisely, the hierarchical organization of knowledge by experts allowed them to access greater and more extensive amounts of knowledge, which are already related semantically or conceptually, for further processing by the cognitive system.

In addition to this structural explanation, the effect of greater domain expertise could equally well be related to the facilitation of underlying processes, by reducing their cognitive load.

Accessibility of knowledge reduces the cognitive load of writing processes

The interdependency of higher-level processes has been investigated particularly well by Kellogg (1987). By starting from the processes distinguished by Hayes and Flower (1980), this author has examined the processing cost of Planning, Translating and Reviewing, as a function of the degree of familiarity of writers with the theme of the (argumentative) text. The degree of familiarity was determined on the basis of a pre-test which allowed to distinguish two groups of adults, either experts or novices with respect to the knowledge domain of the text. The specific methodology to appreciate the respective load of each main writing process was inspired by the classical precept, in cognitive psychology, of the secondary task. During text composition, the writer has to react as soon as possible to a beep (regularly sent every 30 s). Reaction time to the beep is assumed to be longer, as processes allocated to text composition are deeper and more costly (see Piolat and Olive (2000), for an evaluation of the Kellogg's paradigm). Moreover, immediately after the reaction to the beep, the writer has to name the process he was involved in (Planning, Translating or Reviewing). Kellogg's results show that increased degree of familiarity goes along with a significant decrease of the cost of Planning. More precisely, domain expertise essentially facilitates Generating and Organizing of content units, and permits the allocation of more cognitive resources to Translating and Reviewing. By essentially confirming the results obtained by Schumacher, Klare, Cronin and Moses (1984), Kellogg showed that if experts and novices produce texts of equal quality then these texts are the result of different processing loads attributed to generating and organizing: much more of these are required from a novice than from an expert.

To recap, it seems that domain expertise allows facilitation of generating and organizing processes by (1) imposing hierarchical organization of text content (Caccamise, 1987), and by (2) reducing cognitive load (Kellogg, 1987). This has been shown with adults as well as with 7-14 year old children, in a series of experiments all concerning the same domain: baseball. These experiments can also be considered as a series of replications of the same paradigm, with different subjects and age groups. The initial experiments

were carried out by Voss, Vesonder and Spilich (1980), with first year students. The authors distinguished experts and novices about baseball on the basis of a knowledge test (37 multiple-choice items), and asked them to explain in writing the rules of the game. When the organization of the texts written by the two groups were compared, it appeared, confirming the expectations of the authors, that the content of the texts produced by experts contained a greater number of idea units (in terms of the number of actions that were described), as well as a greater number of interrelations, allowing the establishment of a hierarchical organization on the basis of the principal theme of the text. This effect of domain knowledge was replicated with younger participants.

McCutchen (1986) was able to show the same phenomenon with 7-10 year old children, with expository texts (to explain the game of baseball) and with narrative (tell about a game of baseball you saw). Independently of the age, the experts in the domain always produced longer texts that were more coherent in the sense of explicit relations between actions of the game, hierarchical organization of information, etc. These results were again confirmed by de Groff (1987), with 7 year olds. Finally, Benton, Corkill, Sharp, Downey and Khramtsova (1995) asked 14 year olds to revise a narrative containing a scene from a baseball game. The level of knowledge was assessed afterwards by the same questionnaire as was used by Voss et al. (1980). Text content was analyzed in terms of idea units, which were categorized in terms of their level in a hierarchy, which reflected, according to the authors, the functionality of planning processes (generation and organization). The results of this exercise were similar to those of the other studies, in the sense that baseball experts more familiar with the sport produced a greater number of ideas, better organized and more closely linked with the main theme. According to the authors, the effect of domain expertiseADDIN was such that the 14 year olds could produce texts with the same quality as those by older students. Greater availability of domain knowledge limits the cost associated with Planning by facilitating the sub-process of content Generation, which helped the sub-process of Organization.

Finally, concerning the effect of domain expertise on text production, it seems clear that the way in which text content is generated and organized seems to depend to a large extent on the richness and the existing organization of relevant domain knowledge in memory. This conclusion has been confirmed by experimentation with different age groups and conceptual domains. A writer who is expert in a domain

does not produce text in the same way as a novice, independently of age or writing proficiency. This is only one of many aspects of the interaction between domain knowledge and the writing process. In fact, if, as we have just described, domain knowledge affects the way a text is written, then writing a text about a specific domain could also modify domain knowledge. The task of composing a text could be a learning situation by itself. This effect, called epistemic by Eigler, Jechle, Merziger and Winter (1991) explains the fact that a writer is more expert in a domain after having produced a text about it than before the writing process.

2.3.3. The effect of the text on domain knowledge: the epistemic effect

Different factors contribute to the explanation of the (epistemic) power of the written code for learning. Following Galbraith (1992, 1996), two general conceptions may be distinguished here, with quite different assumptions concerning the interaction between writing and learning. They will be called the "classical position" and the "romantic position", respectively (see also Alamargot and Chanquoy, 2001; Munneke and Andriessen, 2000).

Any writer, as an individual or in a collaborative situation, globally has the choice between two general solutions for composing a text: the first option is composing and adapting a text in order to meet the constraints imposed by potential readers, usually not present except in actual interaction. In this case, depending on the situation of communication, the text genre, and individual writing experience, pragmatic knowledge is used for adjusting and arranging content as well as linguistic form according to the characteristics of the addressee. This strategy might be called the classical way of composing a text. The second solution involves that the writer can compose a text by noting down ideas as they come, without explicitly ordering them or reorganizing them in function of some external or internal goal. In this case, which can be called the romantic way of composing a text, a writer does not consider any communicative, pragmatic, or rhetorical constraints, and the resulting text is more like a draft, or a series of notes. It is only in a second phase that the writer considers the constraints of the types mentioned, to be involved in 'classical' rhetorical problem solving, eventually leading to the final text.

It is important to note that both positions imply the creation of knowledge through writing, but each of them stresses different processes as being responsible for learning, and possibly, different

knowledge to arising as a result. In the next sections we discuss both explanations for the epistemic effect of text production.

The epistemic effect explained by rhetorical and pragmatic constraints: the classical position

Writing a text always serves some communicative goal, which requires the linguistic realization of the text to respect a number of pragmatic and rhetorical constraints that permit to reach the envisaged communicative goal. Following Scardamalia and Bereiter (1991), the need for pragmatic knowledge is especially evident in the case of argumentative writing. The function of this type of text is to convince the reader of your point of view, and to reach this communicative goal the writer needs to adapt, modify, and transform individual domain knowledge. Bereiter and Scardamalia (1987) described this manner of text production as the strategy of Knowledge Transforming. This writing strategy involves the writer consciously planning the content of the text, while at the same time managing pragmatic and rhetorical constraints (to persuade, explain, reformulate, to more clearly present an argument, to anticipate possible objections, etc.). This mode of planning can be represented as an actual problem-solving situation for the writer, in which the writer is supposed at a time to deal with constraints concerning the knowledge domain (what do I know?) and pragmatic constraints (how do I say it for this audience?). The activity of adapting text content in function of rhetorical and pragmatic goals and the reverse activity of adapting goals in function of generated text content is supposed to lead to a modification (transformation) of domain knowledge. This "classical" position then maintains that knowledge construction during writing is the consequence of reorganization (transformation) of ideas, a process guided by the rhetorical and pragmatical goals of a text. In this case planning and conception of a text not only involve the generation and formulation of ideas, but also analyzing the rhetorical problem: writing a coherent text with a specific goal for a specific audience.

In his new model, Hayes (1996) tries to deal with the mental processes that could underlie this modification of domain knowledge during text elaboration. Two processes could be fundamental for this knowledge transformation to occur during writing: the process of Reflection and the process of Text Interpretation.

Reflection allows modification of domain knowledge through the elaboration of text content. The reflection process involves mental operations such as reasoning, inference making or any problem solving activity. In this sense it comprises the Planning process, as described in the Hayes and Flower (1980) model. More precisely, Hayes and Nash (1996) distinguish three kinds of planning activities: 'Planning by Abstraction', 'Planning by Analogy' and 'Planning by Modeling'. Planning by Abstraction consists of manipulating and ordering abstract concepts. Planning by Analogy allows generalizing knowledge involved in a specific activity, resulting in a similar or familiar activity (for instance, the generic application of a schema to write a new text, in the case of narrative text writing). Finally, Planning by Modeling, in contrast with Planning by Abstraction, does not bear on abstract concepts but permits the writer to model, as a systemic representation, the situation and task parameters.

The Text Interpretation process allows the writer to (re-) read the already written text and to proceed to a comprehension activity with reference to the written text. The process has a double function. On the one hand, at a local level, it allows a writer to read the already written text to continue coherent text production. On the other hand, at a global level, the process allows revision activities of smaller or larger parts of the text, at a conceptual level (coherent content, for example) as well as a linguistic level (appropriateness and accuracy of linguistic forms).

These two processes, Reflection and Text Interpretation could each play a central role in the modification of knowledge during writing. Reflection supposes that the writer modifies or transforms domain knowledge for incorporation in the text. The three types of planning (by Abstraction, Analogy and Modeling) could each represent a way of modifying and transforming knowledge. These planning or reasoning modes are not specific for writing, but they are mandatory when a text has to be written.

Similarly, the Text Interpretation process requires the writer to take the role of the reader of the text. This activity may lead a writer to modify domain knowledge, to create new conceptual relations, to modify a point of view, to change a problem representation, etc. This mode of learning is related to the analysis of the written text. More precisely, according to Scardamalia and Bereiter (1991) the crucial activity for any writer is to ask to what extent and in what way what has been written (the words, the syntax, implied meaning, etc.) corresponds to the initial intentions in writing the text. For example, when

the writer detects a mismatch between a piece of text and the initial pragmatic constraints, transformation of knowledge may be necessary to solve this problem and to modify the content and form of the text.

To return to the main issue: in the “classical” position it is the presence of rhetorical plans and the constraints imposed them that oblige the writer to constantly monitor, modify, or create knowledge. In the next section, we present a radically different point of view for explaining the epistemic effect: the “romantic” position.

The epistemic effect explained by linguistic constraints: the romantic position

In order to explain the creation of new domain knowledge during text formulation, Galbraith (1992; 1996) contrasts the “classical” position, described in the previous section, with the “romantic” position. This position claims that the modification of domain knowledge during writing of a text will be stronger when pragmatic and rhetorical constraints are weaker. More precisely, according to the romantic conception, the epistemic effect of a text is the result of a dialectic between the writers' disposition and the written text. The 'knowledge-constituting' model's (Galbraith, 1999) basic claim is that the knowledge encoded in sentences is represented, implicitly, within a distributed network of conceptual relationships, and ideas are synthesized by constraint satisfaction within this network, rather than being directly retrieved. The main condition for this dialectic to come into play is a writer trying to express his ideas as propositionally correct sentences that follow each other in one way or another. In this way a first rough draft of a text is develops, not necessarily very coherent, but also different from a list of notes or an organized outline. Only during rewriting of the first draft in a second phase does the writer try to take into account the rhetorical goals of a text. “Rough drafting and outline planning strategies are not just different ways of reducing cognitive load during writing, but also enable writers to better satisfy different social goals. Thus, outline planning has the advantage that it enables the writer to control the way he presents ideas in public, with the disadvantage that, by prematurely imposing order on thought, it may obscure the writer's emerging conception of the topic; rough drafting has the advantage that it better enables the writer to capture his implicit disposition towards the topic, but the disadvantage that the text has to be revised to conform to external constraints.” (Galbraith and Rijlaarsdam, 1999, p. 100).

The writing strategies Outline Planning and Rough Drafting are two different more or less efficient ways of creating new content during writing. While the classical position supposes that constraints support planning (Outline Planning), the romantic position stresses free expression of thought (Rough Drafting). More precisely, it seems that according to the romantic position, the very fact that during rough drafting there are no constraints present for organization, planning or dealing with an audience, is that what allows the activation of the greatest number of ideas. In addition, ideas that are activated and written down give rise to new ideas, in other words, old ideas change because they have been formulated and written down without rhetorical and pragmatic constraints. Only by writing ideas down (as sentences), new ideas can come up. Galbraith (1999) found that individuals that are more sensitive to social constraints, called high self monitors, according to a test of personality (Snyder, 1986), are less good at this, because these individuals tend to more strongly doubt and ponder about pragmatic constraints of the situation.

To return to the main issue again: in the romantic position it is the absence of rhetorical and pragmatic constraints, which allows a writer to be inventive, because then he is not restricted in the elaboration of his thought. The motor of content elaboration is to be found in the constraint of having to express complex thought as words.

2.4. Conclusion about the role of text production

The effect we are specifically interested in here is the epistemic effect of text composition: the very act of writing as a learning experience. Consciously dealing with the audience seems to divide classical and romantic positions with respect to its role in the interaction between writing and learning.

If learning is conceived as the generation of new knowledge (including transformation of existing knowledge), the classic position proposes that actively considering audience needs during reviewing and rewriting a text creates transformations of ideas. The romantic position favors unconstrained idea generation during the formulation of a rough draft as best for creation of new knowledge.

Another important effect on learning is by the linguistic encoding of a message. In the classical position, working on the language of the message (as opposed to its content) in order to meet pragmatic

constraints may have a modifying effect on knowledge. A writer realizes that an idea is different or comes up with a new one when trying to formulate it. The romantic position holds that the process of translating multiple concepts into language (as a sentence) necessarily requires some sort of idea integration. Because you have to formulate a sentence, your ideas are shaped and restructured.

It may be that the classic and the romantic position discuss complementary learning processes. The precise differences between the two may involve the nature of knowledge involved, but also task and situational constraints. As a consequence, the implied learning in each case may be different. Instead of elaborating possible differences, which have not yet been subjected to experimentation, we would like to discuss the implications of each of these positions for modeling by electronic collaboration. It remains to be seen how the power of text production can modify the parameters of communication and learning during collaboration. This is the learning exercise of the next section.

3. COLLABORATIVE LEARNING AS TEXT PRODUCTION: PERSPECTIVES ON FACILITATING COMMUNICATION AND MODELING IN CSCL

The situation that we consider in this chapter involves at least two participants engaged in a problem-solving task, communicating via a network. The course of electronic communication can be taken as a writing process, as discussed in the previous sections. The dialogue between participants can be described as a case of synchronous text production, serving to support problem solving and learning. Many chapters in this volume discuss the oral, face-to-face situation. We want to examine here whether, in order for messages to become tools for modeling, written text production provides added value.

The activities of producing and comprehending written language have been discussed as facilitating learning by:

- Text Comprehension: linking new information to individual domain knowledge;
- Reflection: reflection on knowledge to include in the text by abstraction or analogy, or by modeling parameters of the task situation;

- Text Interpretation: the requirement of interpreting previous text for producing new text, in the light of pragmatic and rhetorical constraints;
- Knowledge Constitution: creating knowledge by writing down ideas.

The question we would like to discuss here is how to arrange a CSCL situation in which these mechanisms are encouraged as much as possible. In fact, given the importance of written text production for sustaining the interaction between writing and knowledge, we can see two possible and complementary points of departure for dealing with this question. The first approach is based on the difference between oral and written code. The second approach distinguishes the classical and romantic positions. Altogether, this leads us to a number of recommendations for arranging an electronic collaborative modeling situation.

3.1 The specificity of the written code, compared to the oral code

Returning to our main proposition, we have to distinguish between oral and written communication, by discussing whether (or when) the collaborative writing situation may provide extra power over the oral condition. In other words, (when) does written language use foster creation of knowledge during collaboration, because (1) it encourages the author to actively try to understand the partner's knowledge and problem representation, and/or (2) it comprises a productive condition for knowledge constitution, or (3) of some other mechanism? Fayol (1996) discusses four dimensions that characterize writing, compared to speaking or oral conversation. These four dimensions could be used to stage-manage some of the parameters in a collaborative learning situation.

3.1.1 Presence of the written trace

The most specific and obvious characteristic of writing is the presence of text. This text is the product of text production, and it is under permanent construction and subjected to additions and changes until the writer decides on its being complete. During a composition process the text can be seen as the trace of its own evolution. For a writer engaged in text production, this implies a double activity: comprehension and production (see Alamargot and Chanquoy, 2001). The text must be read and reread for

two reasons: (1) to preserve coherence with what has been written previously, and (2) to be able to access specific parts of the text quickly and effectively for revision.

In the collaborative situation, the texts (messages) that have been previously received (by the other) or sent (by the writer) may be available and accessible all the time, depending on the interface. This specific characteristic of written code stresses again the importance of the comprehension activity, discussed earlier. In addition, in the collaborative case, the possibility of feedback may lead to revision of earlier text, to more importance and consideration of the other, in the form of more reflection and text interpretation processes, discussed above as two of the learning mechanisms. A first recommendation can be formulated as follows: (I) Support comprehension and revision of produced messages.

One of the options here is to think of ways of clearly representing and organizing information used and produced by the participants. It may be informative for the participants to allow easy and visible changes to information already produced. These kinds of activities should be integrated in the problem-solving situation, to make them useful. In other words, rereading and revising earlier messages should be productive for solving the problem, in order for learning to occur. The issue of representation calls for thinking about ways of representing ongoing discussion. Some possibilities are outlines, diagrams, links, colors, etc.

3.1.2 The absence of an audience

Writing a text normally takes place without the potential reader present, so there is neither interaction nor immediate verbal or non-verbal feedback. Consequently, the individual writing situation requires (depending on the task goal) establishing a mental model of the reader, which requires pragmatic knowledge. We have discussed above the importance of pragmatic knowledge as fundamental for epistemic effects to arise, at least according to the classical position. We return again to this aspect later. Obviously, in the collaborative situation, there is a reader present all the time, who needs to be dealt with constantly. Every time the writer produces a message, the reader-model needs to be accessed. In addition, this model is not fixed, but changes as discussion proceeds. Again, rather precise comprehension of the other's messages is crucial here, a least at the level of pragmatics.

For this comprehension (reflection) to take place in collaboration, grounding needs to be fostered. Grounding can be described as the sense of shared understanding of utterances in interaction (Baker, Hansen, Joiner and Traum, 1999). It is the process during which common ground is constructed and maintained. Grounding should be realized with respect to understanding of the situation, the other participant and the problem solving state. Our second recommendation is based on the conjecture put forward in Baker et al. (1999, p. 46): "Collaborative learning will be associated with a gradual transition from the use of language as a medium for grounding communication (pragmatic) to grounding on the level of the medium itself (semantic), leading to appropriation of the medium". From the perspective of language production as a learning tool we would recommend that the environment (II) Support pragmatic grounding, so as to allow a learner to reflect on the semantics of the situation. This could involve access to (multiple) representations of the problem, the co-learner(s) and of previous dialogue.

Familiar situations and familiar participants make grounding and communication much easier. Discourse production is easier for more familiar topics (see above). For less familiar cases and participants, some representation of the problem solving state, a representation of the problem itself, and a representation of the other, in relation to the problem solving process, should be available, and updateable. In order to monitor ongoing learning, some way of representing what is being learned could help the grounding process. Two recommendations can be put forward here: (III) Represent knowledge building activities, to encourage text interpretation processes, and (IV) Foster reflection by linking conversation to the ongoing problem solving representation.

3.1.3 Processing time

Distribution of processing time is different for written and oral forms. The absence of verbal interaction in the written case allows more time for formulation and reflection. Anyone who has ever experienced or witnessed a chat session, even an educational one, would agree with the observation that it does not permit much room for reflection. Although students may differ greatly with respect to formulation speed and time for reflection, synchronous conversation seems more similar to oral conversation than to writing. This means that the fact that such messages are written may not be enough to benefit from text

power. The time allowed for formulating sentences in individual (or asynchronous!) writing is a crucial factor that not only permits (in principle at least) planning of the content and form of messages at levels other than that of local coherence, allowing reflection on a group of messages to monitor their coherence with respect to a communicative goal (Text Interpretation, see above).

There is an important role for expertise and preparation here. As we discussed above, domain experts need to spend less cognitive resources on planning. For instance, brighter students will be able to more easily communicate their knowledge, the same applies to domain experts. Their messages will be better structured, and because they are more easily produced, domain experts will have more resources left for other tasks. However, research on collaborative learning does not always show positive effects of the presence of domain experts, either students or teachers (Person and Graesser, 1999; van der Linden, Erkens, Schmidt and Renshaw, 2000), and the reverse case has also been observed: two 'wrongs' can make a 'right' if they argue together (Schwarz, Neuman and Biezuner, in press). Although these results are not merely effects of language production, one important point to note is that the fact that text production is easier for an individual does not imply more reflection by default. It may simply mean a faster process, or more resources allocated to things other than learning. On the other hand, the issue of cognitive load may lead students during problem solving to seek "what to do" information rather than "why to do it" information (Sweller, 1994; Katz, Arnois and Creitz, 1999; Veerman, 2000). Reid and Hards (1998) report electronic discussion data that suggest that under time scarcity undergraduates display a greater tendency towards compromise, when this was possible, or a greater frequency of value arguments (i.e. arguments that are not very discussible, such as "Killing animals is cruel") when compromise was not attainable.

Person and Graesser (1999) have analyzed tutoring discourse, especially with respect to question asking. Their research has shown, among many other things, that this type of teaching seems to be effective, although there is very little understanding between tutors and students. What seems to make this type of discourse effective is tutors employing certain conversational moves (hinting, prompting, splicing, pumping and summarizing) which do not lead to a tutor's better understanding the students' conceptions, but nevertheless lead to a student's better understanding of the problem and the concepts involved. One of the general findings in this area is that collaborative learning by instruction requires instruction. That is,

without extensive training programs, participants do not learn effectively from each other's feedback. For example, King (1999) elaborated a successful program for teaching fourth grade pupils to ask thought provoking questions and to understand knowledge construction discourse patterns. Brown and Palincsar (1989) elaborated a program called reciprocal teaching, in which young students are guided towards gradually becoming active, self-regulated learners.

While a slower pace of communication in any type of discourse increases possibilities for reflection, most users tend not to use this opportunity. Among many reasons for this, lack of knowledge about collaboration and lack of motivation for reflection stand out. We would like to put forward two recommendations here: (V) Never stress speed, and (VI) Encourage (and train students for) using free resources for *collaboration*. Experts should try asking the right questions, and novices should try providing real (partial) answers.

3.1.4 Specificity of written forms

With respect to the language forms used, there are important differences to be observed between written and oral language. For example, written language contains fewer repetitions, and it uses rhetorical forms to replace intonation and prosody (e.g. thematization, perspective, etc.). In terms of coherence, written language is less redundant by default. Processing of written language requires more effort to (re) construct the coherence of a message with respect to previous information. Written language requires more conscious application of cohesive devices, including lexical choices.

However, an important limitation concerning this characteristic of writing is that electronic communication involves short messages, especially if it is synchronous. The focus on coherence, which is important for some of the epistemic effects to take place, will have more of a local nature, as it is hard to address all issues at the same time. For example, Veerman, Andriessen and Kanselaar (2000) found that university students discussing (over a network) a conceptual issue during the task of collaboratively analyzing an educational dialogue, had a strong tendency to focus on solving the problem (that is: to select a category from the classification system) instead of trying to find an acceptable answer regarding conceptual issues (e.g.: What does this conceptual category mean? What does the speaker really mean?

etc.). This tendency was stronger in the case of synchronous discussion than with asynchronous collaboration.

Experienced chatters are quite good at overcoming some of the limitations of electronic communication, but this does not (yet) characterize most of our students. Moreover, the use of new language forms in electronic communication may again advance speed rather than reflection. This leads us to suppose that it may not always be a good idea to use oral communication, even when this becomes a serious possibility in electronic environments. It seems that for learning to take place, (VII) Production of well-formulated sentences is important, as well as monitoring for organization and coherence.

3.2 The "classic" or the "romantic" epistemic effect

The points discussed in the previous section represent general recommendations that involve respecting the written textual format and allowing to profit from the power of text production activity. Of course, the collaborative situation is more complex than that, and our recommendations should be related to task goals and also to specific phases during the problem solving process. In addition, most recommendations put forward above may be more appropriate for asynchronous discussions, since they assume that participants have time for reflection. This requirement is different in the case of the romantic position. Knowledge construction is a process during sentence formulation and does not call for reflection on the constraints of the situation. It seems that while conceptual understanding (learning) takes place at the semantic level, the situations and factors that affect learning are to be found at the pragmatic level. In this way, it may be that the romantic position describes an actual learning mechanism, while the classical position describes instructional conditions for learning by reflection taking place. Put differently, the classic conception requires communication to be problematic, while the romantic position requires communication to be supported.

The classic position is about learning by knowledge transformation during problem solving. For communication during collaborative problem solving this implies that conscious reflection should be fostered, by allowing revision of produced text and solutions, having access to multiple representations, and

participants prompting each others' reflection by posing 'why' questions. With respect to the interface, participants need a professional text editor, a text organizer, graphical representations of (partial) task solutions as well as the structure of the dialogue, and perhaps menus for structuring learning dialogues. The instructional situation should incorporate, somewhere at the end, synthesis activities, in which communication is summarized, recapitulated or evaluated.

In contrast, the romantic position is about producing new knowledge during content formulation. The learning situation should encourage unconstrained idea production. Although this could be a characteristic of oral text production, the effort involved in written sentence production is necessary for the effect taking place. In a safe collaborative situation, participants should mutually support each other to produce ideas as much as possible. Maybe the addition of a private notepad for ideas to be shared later could be helpful. We would like to propose two further recommendations: (VIII) Create a safe social environment that supports knowledge constitution, and (IX) Encourage new information to be marked as such.

4. DISCUSSION

The power of text production is only one of the factors important for learning in a collaborative situation. Our recommendations could run counter to other interests in that situation. For example, we do not want to overload problem solvers' views with too many processes to monitor. Computer screens should be customizable in this respect, according to a user's experience and requirements of a specific state of problem solving. This requires great design intelligence, surpassing that of current word processors.

The social dimension, crucial for any collaborative learning situation, is largely ignored in our paper. The social dimension cannot be studied in isolation; neither can any effect of collaborative learning be completely understood without reference to the interaction between individual and situation in terms of the social dimensions. We propose to do that in a later text, which focuses more specifically on knowledge constitution, for which the social dimension of collaboration is more important than for the 'classic' positions. The new model of Hayes (1996) contains a box with a social dimension, including collaboration,

but there are few ideas about how and why interactions between social and other dimensions must be incorporated (see Alamargot and Chanquoy, 2001, for a review). Eventually, it can be envisaged on the basis of the knowledge constituting model by Galbraith (1999), that the acquisition of knowledge in the romantic manner by writing down what comes to mind, will be more effective when the writer is less affected by the social context of writing, as it is reflected by pragmatic and rhetorical constraints. It may be interesting to find out more about the role of individual differences in this respect, for example by investigating how these different social sensitivities are reflected in communication and learning by writing. This social perspective on interaction should be more explored.

Similarly, research has provided us many explanations for learning effects of collaboration. It is sometimes hard to distinguish in terminology and explanations between cognitive learning processes and the effects of instructional intervention or training. Conditions under which these mechanisms come into play involve task situations, individual characteristics and the nature of the domain. All these mechanisms involve verbal interaction. We would like to try to answer the question to what extent language use contributes to (or may even explain) the learning effects proposed for collaboration, but that is currently not possible. To illustrate, we list here some possible cognitive learning mechanisms, operating in collaborative learning, as proposed in Dillenbourg (1999):

- Induction: the learner induces new or more abstract information as a result of analysis, for example by comparing information from different sources or different representational formats. This seems also to be a possible effect of (oral) language use, for example as suggested by Schwartz (1999, see above).
- Cognitive load: as we have already discussed for the case of writing, domain experts have more free resources for complex processes because less energy is required for them to generate domain knowledge in a useful format. Expertise (whatever type) present in the collaborative situation could free resources in the same manner. It is up to instruction and the participants to see to fruitful allocation of these free resources.
- Self-explanation: one way of viewing collaborative learning is as a situation in which individuals provide explanations to one another. That self-explanation as constructive cognitive activity can

lead to modification of knowledge is an established research finding (Chi, Bassok, Lewis, Reimann and Glaser, 1989; Chi and VanLehn, 1991). Explaining to others seems to offer even more opportunities for learning, when compared to self-explanation, but no substantial significant differences seem to have been observed so far (Ploetzner, Dillenbourg, Preier and Traum, 1999). Baker (1996b) discusses evidence that one of the main effects of dialogic argumentation is that it makes knowledge explicit, leading participants to reflect on and restructure knowledge.

- Conflict: a discrepancy between knowledge or viewpoints leads to conflicts, discussion, and eventually, learning. Conflict, in the sense of Piaget (de Lisi and Golbeck, 1999) induces revisions in the cognitive system because an individual may look for alternative arguments or solutions. A collaborative situation may induce discrepancies between individuals, which need to be reset to equilibrium state, a process that may result in revision of knowledge. A change may be behavioral, based on social pressure, but not cognitive at all (e.g. Stein and Miller, 1993; Baker, 1996a).
- Internalization: transfer from the (social) situation to the inner plane, especially examined in the context of child-mother interactions (Wertsch, 1985), where a child becomes able to use new concepts by verbal interaction with a parent, essentially through reflection, it seems.
- Appropriation (Rogoff, 1990): reinterpretation of actions or concepts in the light of what the other says or does. This could be a long-term process, which has properties of socialization, but short-term effects of linguistic production have been reported (Fox, 1987). During interaction, as a result of grounding, learning may take place, by virtue of appropriation of tools (Baker et al., 1999).

We leave the question of the role of language use in these learning mechanisms open here, as there is no experimentation we know of to explain learning by collaboration in terms of effects of message production. This is for us a challenge for the near future. In general, this means experimenting with knowledge activation of participants producing written messages in collaborative learning situations. This type of experimentation may clarify some of the complicated results and difficult-to-relate mechanisms that have been proposed to explain collaborative learning.

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Index - Key words