Full paper refereeing- (accepted abstract GIA01181)

Giardina Max

Associate Professor/Director of SMILL (Sydney Multimedia Interactive Learning Lab)

University of Montreal/University of Sydney

University of Sydney, Faculty of Education A-35, Educational Psychology and Learning, NSW, 2006, Sydney.

11/13 Harriette St., Neutral Bay, NSW 2089, Sydney.

Tel: 02-93513113; Fax: 93512606.

m.giardina@edfac.usyd.edu.au

Laila Oubenaissa

Lecturer/Associate Researcher

University of Montreal/University of Sydney

University of Sydney, Faculty of Education A-35, Educational Psychology and Learning, NSW, 2006, Sydney.

11/13 Harriette St., Neutral Bay, NSW 2089, Sydney.

Tel: 02-93513113; Fax: 93512606.

l.oubenaissa@edfac.usyd.edu.au

Title

The Activation of High Order Cognitive Skills such as: Argumentation, Negotiation and Restructuring of knowledge by Distributed Cognitive Tools.

Type of Presentation

Individual paper

Max Giardina

Laila Oubenaissa

Abstract

The emergence of problems concerning information technologies and learning, are related to the impact of new constraints and access modalities and information communication and organisation on the learning process. It is even more related to the new cognitive skills required by the learning environments integrating these technologies in order to understand and exploit all their potential. This concern led us to conceptualise a Pedagogical Mediation Structure (PMS) construct. Several pedagogical principles and strategies allowed us to elaborate a new theoretical and operational model. The first prototype gathering nine cognitive tools was developed and validated. In the framework of this research, we were interested in the skills related to the process of negotiation, argumentation and knowledge restructuring. We sought to make the theory of cognitive flexibility operational using cognitive tools that manage and organize the interaction process among student pairs and the accessible information in a mediated distributed learning space. During students' interaction with PMS's cognitive tools, we observed the behaviours, the process and the strategies used and manifested by students whilst negotiating, arguing and restructuring. We also explored the construction of student comprehension, trying to describe it in terms of flexibility, knowing the socio-cognitive and meta-cognitive context in which it was elaborated.

Key Words

ICT in distributed learning spaces ; high cognitive skills.

Introduction

An analysis of reports and articles that deal with the use of Information and Communication Technology (ICT) reveals that there are currently more questions than there are answers when it comes to the positive impact of these new technologies on learning. The results of the research put more stress on the fact that when it comes to these technologies, the field is wide open for a new examination of the ways in which students learn and construct knowledge and of the numerous possibilities for innovation in teaching (Giardina et al., 1997).

DMLE and its effects on learning

It is an established fact that the use of Distributed Mediated Learning Environment (DMLE) has undeniable positive effects on a learners' motivation, on their attitudes to certain subjects (Young, 1998) and on the quality of their reasoning and reflection (Clark and Crail, 1992; Steinberg, 1989; Marttunen, 1994; Cohen and Scardamalia, 1998). It is also understood that these positive effects are usually limited to subjects who have developed a well-defined learning profile (Jacobson and Spiro, 1995; Jonassen, 1993; Gall and Hannafin, 1994). Many research groups accept that using these new technologies brings along with it a multitude of new problems such as the cognitive overload brought on by the use of many and varied symbolic systems, the navigation problems related to the hypertext format of the data, and the way that controls and choice options are set up (Hill and Hannafin, 1997; Nielson, 1990). Dillon (1994) and Rouet et al. (1996) stress the fact that in education we are only just beginning to interpret and understand certain aspects of these emerging problems by means of theories of the psychology of understanding. If so there remains much work to be done in relation to the steps taken to conceive and design DMLE.

The clash between what is technologically possible and what is important in the learning process is not a new one. In fact, when the computer was introduced into the classroom in

the 1980s, there was no thought given to including socio-cognitive and socio-affective aspects in the design of computer-directed or computer-programmed instruction, for example in 'practice and drill', and 'machine as teacher'. It is also true that the development of DMLEs is currently occurring without any great consideration for the limits and constraints defined by the cognitive theories related to an individual's capacity to process data, perception, selective attention, the management of different symbolic systems, work memory and so on. This oversight is not new and is in no way linked to the use of new technologies. It has been analyzed and critiqued for some time by more than one researcher, including Pintrich (Pintrich et al., 1993) who decries the fact that in education we have never managed to reconcile the "cold-model" of cognition grounded in logic and science with the "hot-model" of cognition grounded in emotions that affect the learning process.

Furthermore, by diversifying the learning space, DMLE make it more complex. The more these environments try to reproduce the complexity of current knowledge by playing on the diversity of modes of access and representation, the more they serve, according to some authors (Gall and Hannafin, 1994; Nielson, 1990) to disorientate and confound the novice and intermediate learner. We are, however, aware of the fact that research in this domain could easily be called exploratory, where innovation is largely ruled by what is technologically possible. In terms of managing the cognitive and socio-cognitive process, this technology has generated as many problems as it has possibilities. This is largely due to the fact that the learner in this environment subjects the effects of his interaction with the DMLE tools (manipulation, choice, navigation, options, etc.) to his interaction with the members of a community (cognitive conflict, interiorisation, negotiation, argumentation, etc.) (Oubenaïssa, 2000). During the analysis of DMLE (Oubenaïssa, 2000), we noted that several of these environments are based on specific theoretical foundations and a particular concept of learning and knowledge construction.

However, according to Land and Hannafin (1995, 1997), and Perkins (1993), there exists no design model or approach which defines the relational properties of DMLE. Furthermore, it seems that educational research is beginning to understand and to analyze the effects on the learner of interacting with and using these environments (attitudes, skills, etc.) while also defining new profiles and probably new styles and difficulties of learning associated with these environments.

The majority of DMLE manage to operate more or less according to Vygotsky's concept of the zone of proximal development thanks to a technology which is becoming smarter and more sophisticated (Chan, 1996) and which allows us to place the learner on the 'intermental' level. But is it the conditions and the contexts which promote the more individual dimension of Vygotsky's concept (Vygotsky, 1978), that of the 'intramental' level?

We also recognized that in these DMLE, we are seeing the juxtaposition of two elements of concern. The first in relation to an interface whose primary concern is to organize and facilitate transactions between the system and the user. The second is more concerned with mediating the process of interaction and communication. It occurs to us that there is room in these environments for a more specific concern. This would be the development of skills and the mediation of cognitive, meta-cognitive and social activities which presuppose these skills. It is exactly this notion which is at the heart of the development of the Pedagogical Mediation Structure (PMS).

PMS : Pedagogical principles and the development of skills

The aim of the PMS is to develop the following skills:

- Argumentation and negotiation, given the fact that DMLE are the meeting and interaction point between several subjects supporting diverse beliefs and knowledge. These skills are also necessary given the increased exposure of the learner to different points of view regarding one piece of information.
- The restructuring and refining of knowledge, given the fact that DMLE are the place where information and knowledge is constantly being renewed and acted upon. These skills become necessary as a consequence of the social activity of knowledge construction where all information is a source of debate.

Certain pedagogical principles, recommended for the development of the skills in question, defined the cognitive tools that we used in the PMS. These cognitive tools are aimed at providing optimal conditions for interaction and communication in terms of the time and diversity of students' feedback.

How fundamental theories can help get the most out of DMLE

The proliferation of DMLE has been matched by a large number of new conceptions of learning as an activity and a product. On the one hand, it has allowed us to bring the concept of cognition up to date with the theory of distributed cognition, with the importance it places on representations (internal and external), and the 'affordance' of tools and actions (potential of action) in the process of acquiring and processing data (Salomon, 1993, Pea, 1993, 1994, Perkins, 1993, Cole and Engelstrom, 1993, Winn, 1993; Zhang and Norman, 1994; Dillemburg, 1996).

During our development of the PMS, we also sought to extend the position of Spiro and others. These researchers work on ways of promoting cognitive flexibility that go beyond the concerns of information access and representation. These methods target the development of a learning context which is favorable to the diversification and construction of mental models and diagrams. We did, in fact, attempt to find a modus operandi which used diverse forms and modes of interaction and communication between the peers and the teacher in order to promote cognitive flexibility.

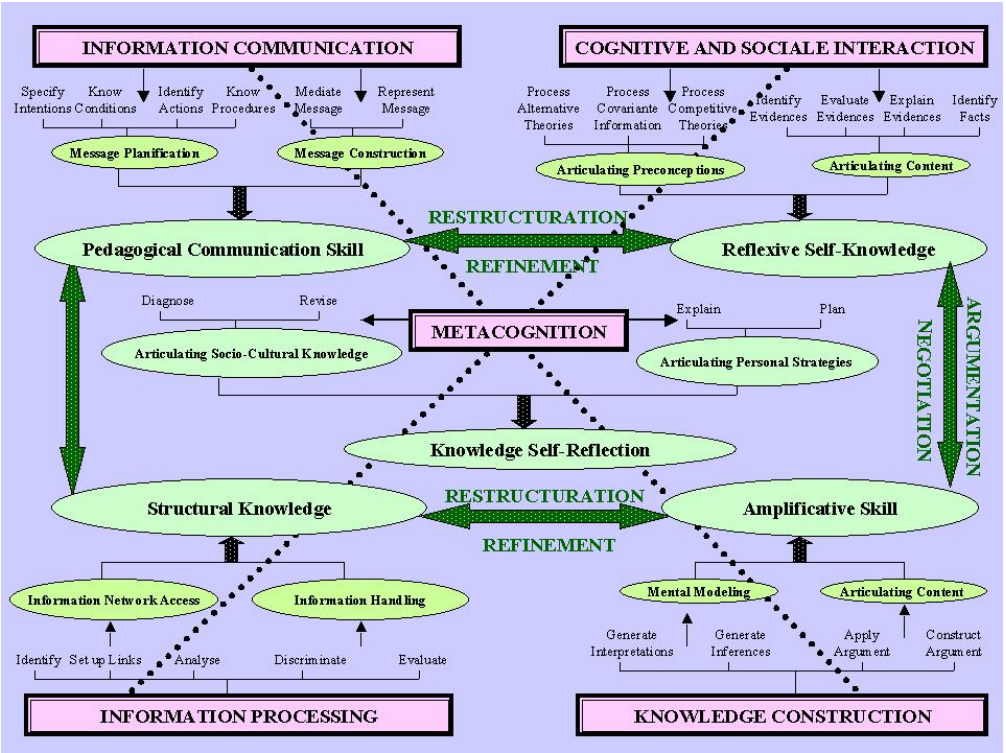
The theory of cognitive flexibility (Spiro, 1987; Spiro et al., 1991; Jacobson and Spiro, 1995) allowed us to structure the access to information so that the subject was involved in a process of flexible learning, by developing a skill for interacting with different types of information. We wanted to approach cognitive flexibility as a learning product with ties to the concept of epistemic fluency (Morrison and Collins, 1995) and the concept of game and form (Morrison and Collins, 1995, Pea, 1994). We thought that if we added the cognitive tools from the PMS to the DMLE, then we could integrate not only information and communication technologies but also use the principles related to communication and interaction in order to improve the learning process and activity.

Throughout our research, we were also interested in seeing what type of understanding the subject would build while interacting with a learning space structured by our PMS. We envisaged that the cognitive tools used in the PMS would allow the practice of different epistemic games and forms and that this learning space would be a place for developing an epistemic fluency manifested by a flexible understanding of the information accessed by the learner.

We believe that new technologies do not push individuals to argue or negotiate or become more collaborative. These technologies simply create richer and more favorable contexts and conditions in which to interact socially. It is, therefore, important when constructing the DMLE to ensure that the social interaction offered by these technologies is accompanied by the development of cognitive, meta-cognitive and socio-cognitive skills necessary for the

refinement and building of knowledge. We kept this in mind, along with the results of research into negotiation, argumentation and restructuring of knowledge, when we formulated the theoretical model of the PMS. The PMS model can be defined by the following five axes of intervention (Fig. 1):

- Pedagogical Communication of Information.
- Knowledge Construction.
- Meta-cognition.
- Cognitive and Socio-cognitive Interaction.
- Data Processing.



Each intervention axis (eg. cognitive and social interaction) (fig.1) is aimed at achieving a particular higher-order learning product[1] (eg. reflective self-knowledge). These axes also describe learning activities (eg. finding evidence, processing co-variant data etc.) by which learners may progressively construct learning sub-products (eg. articulating of pre-conceptions and content etc.). The model acts on several different levels: the intervention axis, learning activity, learning sub-product, learning product and skill. The convergence of certain higher-order learning products contributes to the development of skills. By reviewing the literature we are able to situate exactly where these skills lie. We are of the opinion that it is social and cognitive interaction plus knowledge construction that together contribute towards the development of skills in argumentation and negotiation. The skills of restructuring and refinement will benefit from the learning products tied to data processing and knowledge construction as well as the products tied to information communication and social and cognitive interaction. This perspective reinforces our analysis of the literature that identifies and defines the optimal conditions for developing the skills in question.

The operationalisation of the PMS may also be seen as a way of utilising the principles attached to the development of skills for the organization of learning activities and teaching strategies[2]. This also enables us to look at complex skills such as argumentation, negotiation, knowledge restructuring by means of learning products related to data processing, the process of mental modelling, the enumeration of knowledge and content,

and the communication of information. The development of a first prototype was made in collaboration with the company Novasys of Montreal.

In the first version of the PMS prototype, we developed nine cognitive tools, each having a structure that encouraged diverse feedback. The tools comprise:

- Forum.

- Initiating Discussion.
- Asking for an Explanation.
- Asking for a Demonstration.
- Question & Answer.
- Analysis.
- Problem-Solving.
- Presenting one-self.
- Guided Tour.

It is equally important to note that this PMS creates a real learning space that permits a diversified interaction between the peers and the teacher while interacting with the mediated course and the learning activity.

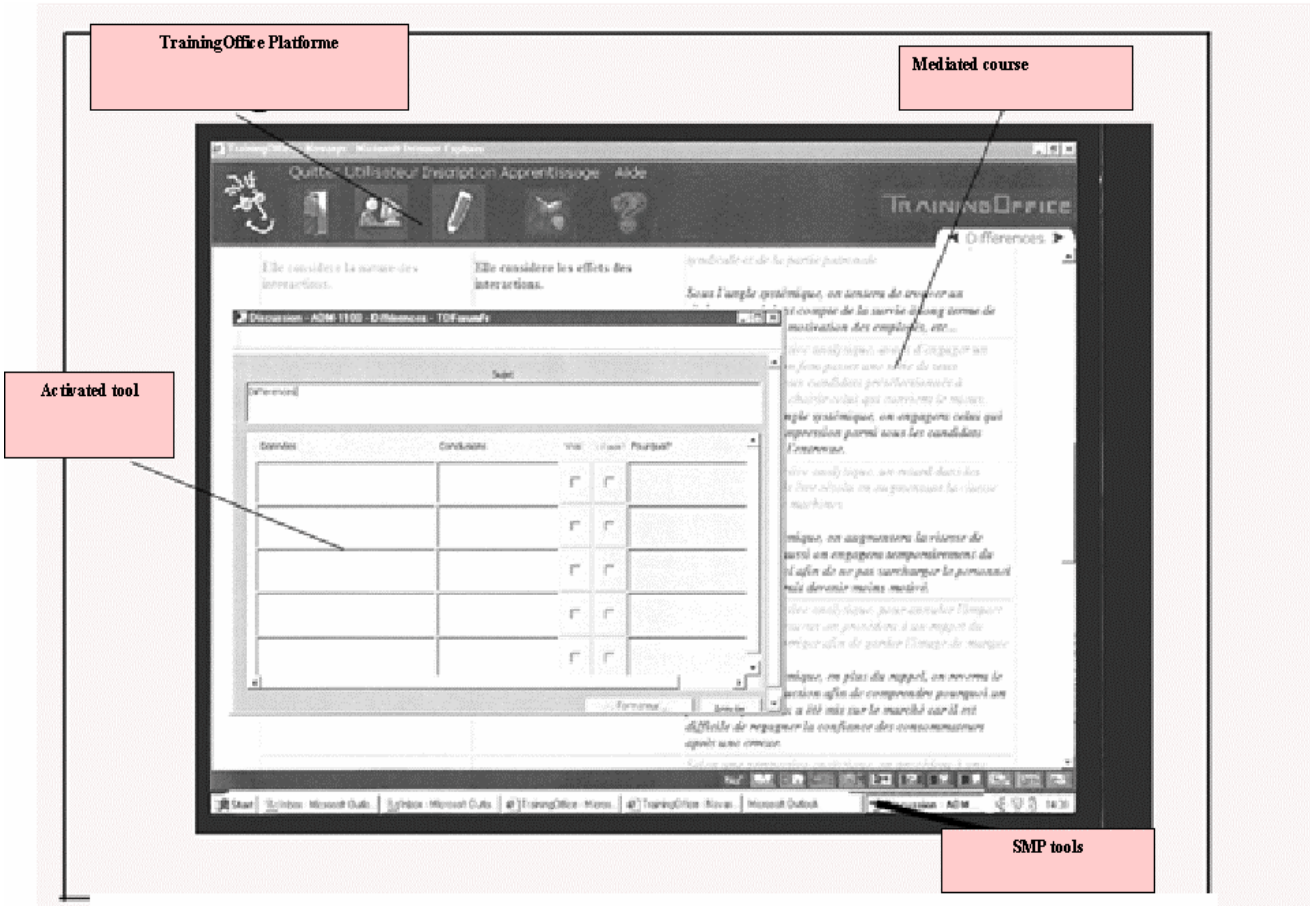


Figure 2 :Visualisation of PMS prototypes' screen-page with the tool Start Discussion activated. The cognitive tool icones (9) are on the bottom down of the page. The SMP allows student to interact with mediated course that are supported by existing TrainingOffice Platforme.

Figure 2 gives an example of the tools used in the PMS and shows how it became integrated into the existing Novasys platform "Training Office".

Testing the PMS prototype

In testing the first PMS prototype we wanted to observe and analyse the cognitive processes of the students while interacting with the prototype, where they were given an authentic learning task based on the resolution of a case study. We were interested in the skills of argumentation, negotiation, and knowledge restructuring. We were also aware of the complex circumstances surrounding the manifestation of these skills. So, we opted for the approach recommended by Huberman and Miles (1991), an approach towards qualitative research that would enable us to triangulate the data.

Therefore:

- As students interacted with the prototype, we used a verbal protocol, an observation grid, and electronic tracking of messages and actions in order to pinpoint the type of tools used, the amount of use and the exchange cycle that each PMS tool allowed.
- After the students finished interacting with the prototype, we developed a semi-structured interview with 32 questions, as well as a form for the factual data.

To analyse the behaviour and processes that were observed, we used descriptive scales that described and categorised the actions and behaviour of the students relative to the skills studied. These analytical instruments were:

- The levels of consciousness scale (Pontecorvo, 1987);
- Knowledge construction activity scale (Scardamalia and Bereiter, 1991);
- Intimate negotiation coding system (INCD) (Ting-Toomey, 1982)
- Communication strategies in negotiation (Wallaces and Skill, 1987) and;
- Argument criteria (Toulmin et al., 1979 and Kuhn, 1992).

Using the information gathered from the students, we set up a database for each skill (behaviour and cognitive actions), based on the categories in these descriptive scales. This allowed us to establish relationships and calculate percentages.

To analyse the verbal protocol we looked at the cognitive tasks over the whole of the processes identified in the literature as being prerequisite to the activities of negotiation, argumentation and restructuring such as: analysis, inference, interpretation, explanation etc. The analysis of the student's actions and behaviour was then done in relation to these cognitive tasks. We also used electronic tracking to study in detail the use of each PMS tool, the exchange cycle allowed by each tool and the different states of each tool[3] throughout the entire testing of the prototype.

Results of the testing of the PMS prototype

The testing of the prototype had two objectives. The first was the analysis of the learners' cognitive processes relative to the skills of argumentation, negotiation and restructuring of knowledge. The second was to see if our observations were a result of the learner's interaction with the PMS tools. To achieve this, we analysed the learner's actions, behaviour and message as well as the qualifiers that the students used to describe the tools and their impact on the learning activity in which they were engaged.

Frequency and use of the PMS tools

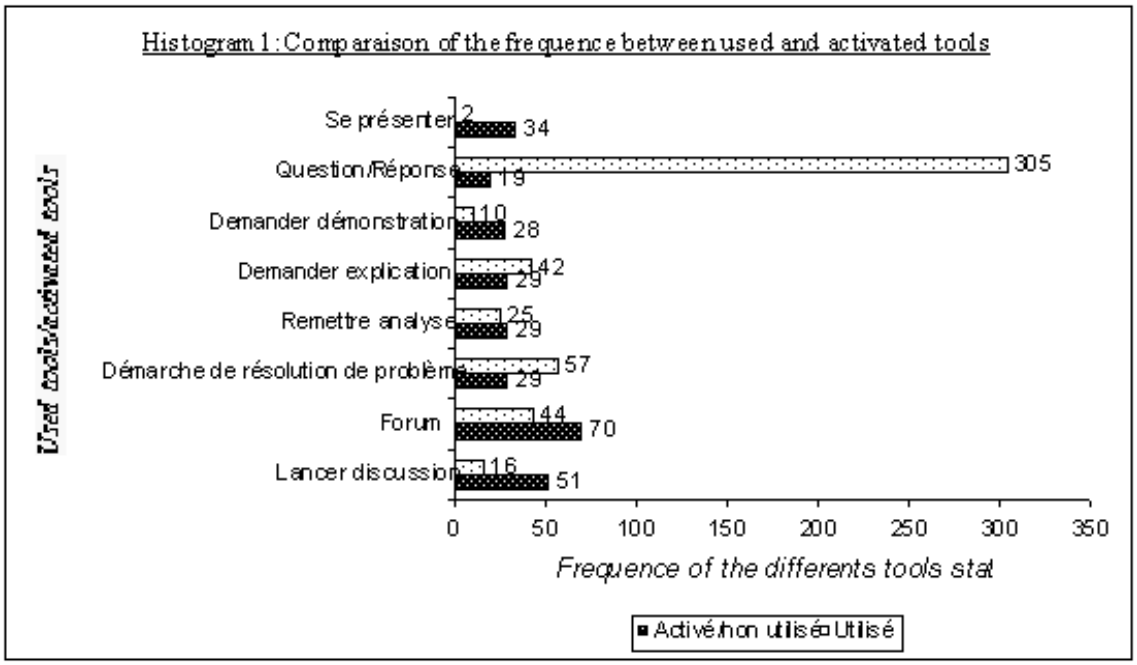
Electronic tracking enabled us to study the interaction of the students with the PMS tools. It was important at this stage to see which tools were mostly used. Also important to distinguish between the different types of interaction that occurred between the students and

the tools (activated tool and used tool[4]) and lastly, to study the cycle of interaction from the perspective of the time taken to send and receive messages while using each PMS tool. This last aspect allowed us to verify if the time taken to interact with a tool had an effect on the students' use of them.

It appears that the tool most used by the students was the Question/Answer tool. By looking at the first histogram, we can estimate that this tool was used about three times more than the second tool and a little less than all the tools put together.

Since we were dealing with cognitive tools[5], we were anxious to see if the simple presence of a tool could help trigger the interaction process. We made the distinction between the interaction of the tool, which consists in interacting with the format, and the functionality of the tool, either the activated tool (without using it), or the used tool, where the student uses the format and functionality of the tool to compose a message.

For each tool, we counted the number of times that it was activated only, and the number of times that the activation of the tool gave rise to its use in order to compose a message.



From this histogram four trends can be observed:

- Tools that were generally used after being activated. In decreasing order one finds the following tools ‘Question/Answer’ and ‘Problem-Solving’;
- Tools that were activated more but not used very much. In decreasing order the tools: ‘Initiation of Discussion’ and ‘Forum’;
- Tools that were generally activated less and used very little. Here one has the tool ‘Introducing oneself’ and ‘Requesting a Demonstration’.
- Tools that were generally used each time they were activated. In this category we find mainly the tool ‘Analysis’ and ‘Request for Explanation’.

The tool that was most used was the ‘Question/Answer’ tool, as well as the ‘Problem-Solving’ tool. As far as the tools that were activated more often than they were used, there is

the 'Initiating Discussion' tool and the 'Forum' tool. Finally, as for the rarely activated and rarely used tools, there is the 'Introducing oneself' tool and the 'Requesting a Demonstration' tool. In regards to the 'Requesting a Demonstration' tool, the students stated in their observations that they usually got no response with this tool so they dropped it. As for the 'Introducing oneself' tool, it appears that it was not relevant as far as the students were concerned since they already knew each other.

Interaction profile and sequence of tool use

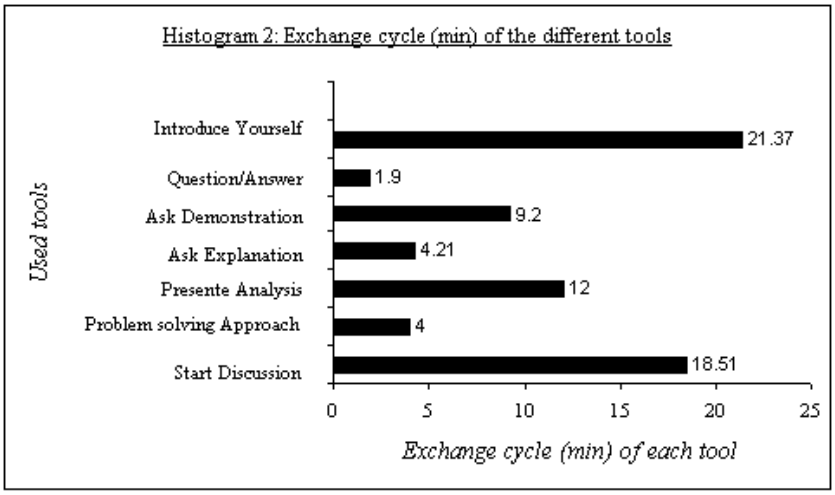
The aim of this analysis is to use these tools to check the type of sequences of interaction which we call 'usage profile'. We were also attempting to see whether more than one student had the same sequence of tool usage.

By analysing all the students' transactions, we were able to identify usage profiles which were directed more at exploring, ie. the learner activates the whole set of tools but only uses one or two particular tools. Others exhibit a two-step profile. At the start of the interaction, most of the tools are merely activated. Towards the end of the interaction tools that were only activated before are used to interact with each other. We also observed the existence of a usage sequence that is generally found for all students, namely, the activation of one specific tool before or after the use of one specific tool. In this category, the sequence that very often recurs is the 'Question/Answer' tool along with the 'Forum' tool, the 'Initiating Discussion' tool with the 'Analysis' tool.

Exchange Cycle

In order to have a better understanding of the students' interaction with the PMS tools, we also tried to discover whether the students' use of a given tool was affected by the time it took to use it to accomplish the task and receive feedback. This is important because the time and nature of the feedback are key components of the pedagogical principles that are a part of the theoretical PMS model.

Since the PMS tools can be distinguished by the nature of the feedback that they offer and the time it takes for them to give this feedback, we have defined the exchange cycle as the time it takes the sender to formulate the message and get feedback. We then calculated an exchange cycle for each tool. Histogram 2 displays the results of this analysis.



The shortest exchange cycle, one minute and nine seconds, was delivered by the ‘Question/Answer’ tool. The ‘Problem-Solving’ tool yielded an exchange cycle of four minutes. The ‘Request for Explanation’ tool took four minutes and twenty-one seconds. These were respectively, the most used tools and the tools generally used after being activated. It should also be noted that the longest exchange cycles were associated with the ‘Analysis’ tool at twelve minutes, and the ‘Introduce Yourself’ tool at twenty-one minutes and thirty seconds. The latter was included in the category of tools that were generally used after being activated.

The analysis of the electronic tracking consequently showed the existence of a link between the use of a tool and the time and/or the nature of the feedback that the tool offered at various stages of the learning activity.

Verbal protocol

By looking at the content of the verbal protocol in terms of the student’s actions (the movements and displacement of the cursor, the learner’s movements and words), we were able to analyse them in terms of cognitive processes and activities such as: analysis, position-taking, decision-making, and anticipation. This analysis shows the use of tools involves students in a process of analysis, anticipation, position making, decision-making, and the planning of their interaction. Thus, the use or the simple activation of a tool makes the student aware of the different stages of the cognitive activity in which he is involved. He is also aware of the nature of the feedback that is expected of one another, as well as of the nature of each other's contributions (that’s an opinion, that’s an observation, that’s not very scientific etc.) The students also assessed the validity and clarity of each other’s statements. We also identified recurring behavioural patterns amongst all the students by analysing the movement of the cursor. Thus, when students receive or write a new message, they seem to be concerned with checking the relationships that have already been established or are yet to be established between different types of information such as data, conclusions, explanations etc.

While using the tools, the students also commented on the clarity and relevance of the messages and their peers' contributions. They criticised each other for asking questions but not offering any solutions. Some students commented on the sometimes excessive use of the 'Question/Answer' tool and go on to say that this is due to the fact that certain tools are more demanding when it comes to formulating a message, such as 'Forum', ‘‘Problem-Solving Approach’ and 'Start Discussion’.

We also observed that upon receiving a message, they often placed the cursor in the feedback space before they even read the message. This action was often accompanied by a clarification of the sender's expectations. For instance, upon receipt of a message composed with the help of the 'Problem-Solving’ tool, often the students would say something like "I have to comment on his analysis of that." The same actions were also observed during the composition of the message. In this case, when the student was about to send a message to the forum, he would say something like "he's got to let me know if he agrees with me or not."

It seems that the interaction with the format or the structure of a tool leads the students to anticipate the nature of the reply that they are going to receive from each other. The students even go so far as to anticipate the time it will take for them to receive an answer to their message. The analysis of the information gathered from the verbal protocol allows us to draw some conclusions about the impact of the use of the PMS tools on the actions and behaviour of the students (Table 1).

Table 1: Results of thinking aloud analysis related to cognitive process. For tools: PSA: Problem Solving Approach; Anly: Give Analysis; SD: Start Discussion; Expl: Ask Explanation; Q/A: Question/Answer.

Process	Actions and behaviors expressed amd manifested by learner	Tools
Analysis	Identify tools' elements. Nome activities that must be done do or supposed to ne done . Navigate among messages' element while writing and navigate between the different information spaces when receving a message or at the end of its writin. Write message seeking and using key words and concepts. Seek precise information within the course.	PSA Anly. Forum SD. Expl.
Planification	Manage peers discussion. Establish the nature of the information and intervention while activating tool. Define length and characteristics of the message to write. Direct information seeking around defined concepts from the activated tool. Define the goal and the activities to do.	S.D. Q/R
Position making	Comment pertinency and clarity of peers messages. Reproch to peers the fact that they only ask questions and do not suggest solutions or formulate propositions. Appreciate tool PSA and Anly. Express himself on validity of information and on types of feedback received. Find difficult to formulate conclusions using tool : Anly., SD and Forum.	Q/R Anly. PSA SD.
Decision making	Try to establish coherency of the message (eliminate or rectify all automatic system decisions). Establish which message to answer and which could only be consulted. Establish his actions and choose depending on his preferences	Forum. Anly. SD.

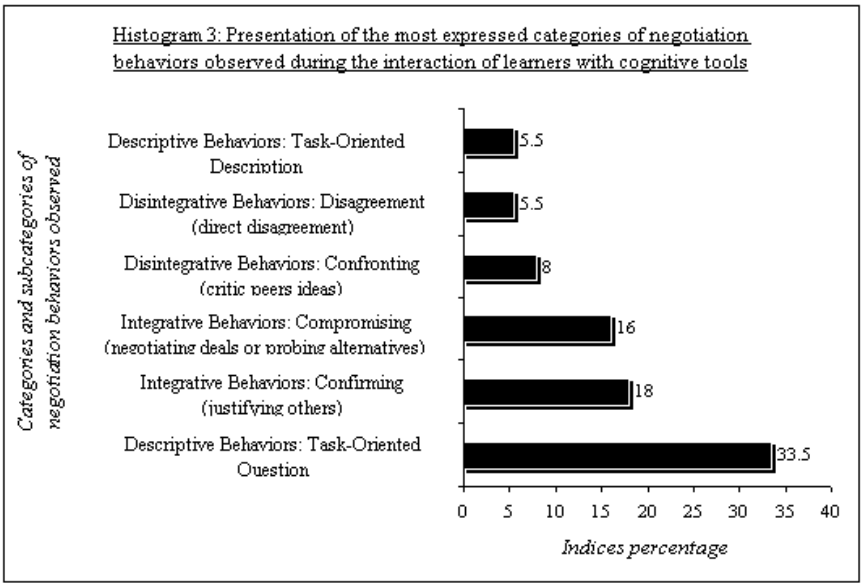
	and usefulness. Choose the options that allow him to have control on message coherency, quality and relevance of feedback. Determine his actions and activities to be more effective.	
Anticipation	Make explicit peers expectation when his receive their messages. Make explicit peers expectation in terme of which kind of feedback they waiting from him. Estimate how much time he has to wait to have peers or tutor response.	Q/R PSA Anly.

It appears that certain tools have more effect on students' behaviour and actions than others. These findings are very important referring to the definition of a cognitive tool as tool that organises our understanding and our process of knowledge acquisition, as well as a tool that allows the restructuring of a cognitive activity.

Data concerning the process of argumentation and negotiation

Negotiation

The analysis of messages formulated by the students in interacting with the PMS prototype also allowed us to identify the behaviour and communication strategies manifested by the students that are related to negotiation. As for negotiation behaviour, we observed a predominance of the integrative and descriptive categories with percentages of 42% and 40% respectively. The disintegrative category came in at 18% (see Histogram 3).



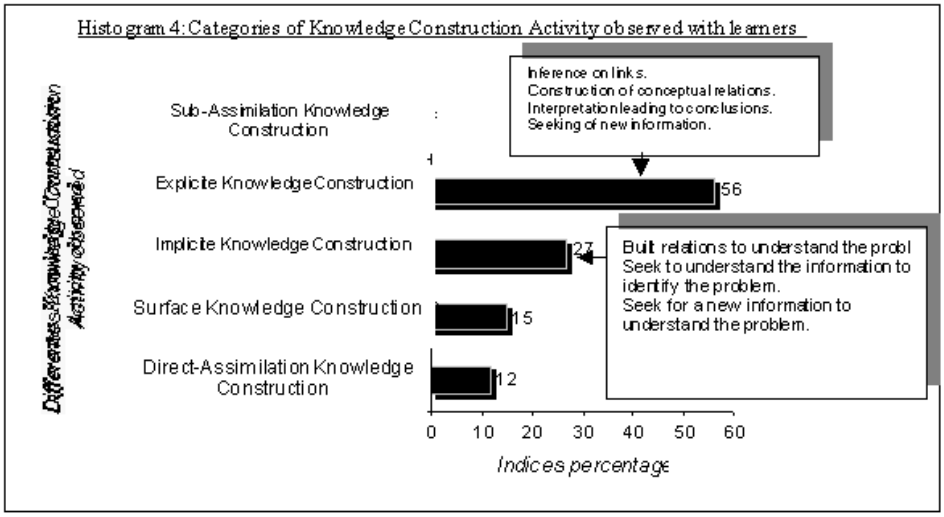
The analysis of sub-categories of behaviour identified in the messages was evidence of an interaction between peers, hinging mainly on the confirmation of the other person's statements (justification and support), the search for compromise by discussing adherence to the other's opinions and arriving at agreement through brief argument. The predominant sub-category, however, remains the Task-Oriented Question. Furthermore, the communication strategies used most by the students were the assertion of argument, questions, support and settlement.

Analysis of the indices related to the process of negotiation, behaviour and strategy shows up three aspects that are very important to our research. First is the presence of an integrative behaviour (42%) in consideration of the process of negotiation (confirmation, compromise and agreement). Second is the predominance of the sub-category of the Task-Oriented Question that supports the process of negotiation as having finality: the achievement of an objective, accomplishment of a task, arrival at agreement etc. Third is the predominance of communication strategies (assertion of an argument, question, support and settlement) and the manifestation of disintegrative behaviour (18%) (disagreement and confrontation) which support the students' involvement in a process of argumentation (Oubenaïssa, 2000).

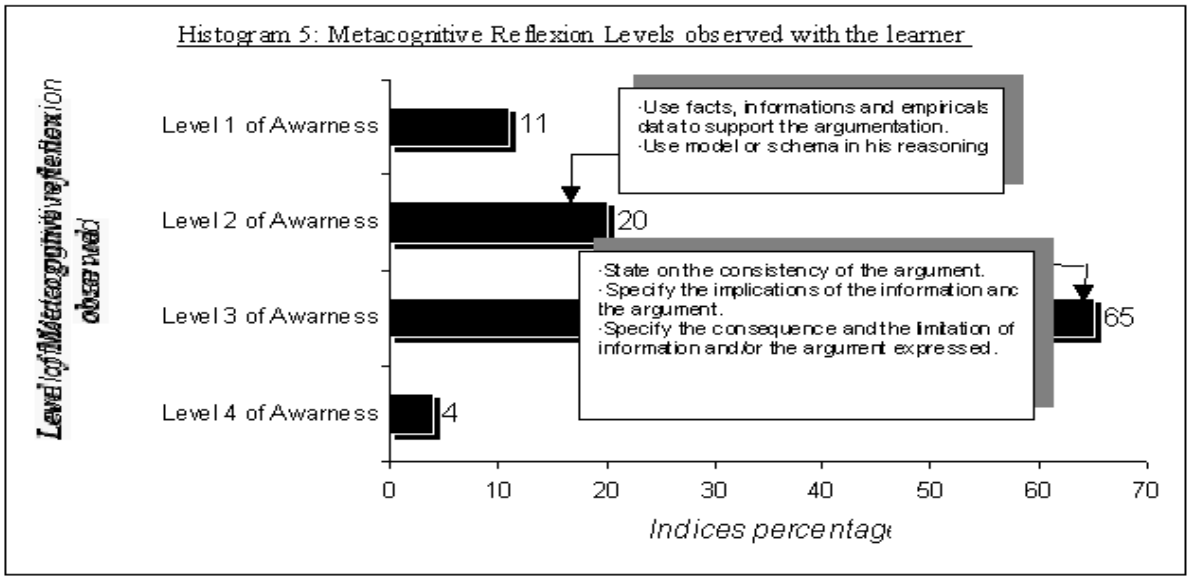
Detailed analysis of the *integrative behaviour* showed that the students focussed their interaction on peer support and the negotiation of alternatives by offering new information and engaging in explanations and justifications. As for the *disintegrative behaviour*, the students did not stop at the rejection of the other's comments but expressed their position by criticising or attacking the consistency of the information conveyed. For the *descriptive behaviour*, the students' messages show a predominance of questions requiring explanations, clarifications and information regarding the process of problem solving, procedures and approaches to the case study. More social questions hardly entered into the equation.

Argumentation

We used the Scardamalia and Bereiter scale (1991) and the Pontecorvo scale (1987) which deal with knowledge construction activity and levels of reflection to gather information on the three skills of argumentation, negotiation and knowledge restructuring. Detailed analysis of the messages showed that knowledge construction (explicit knowledge construction activities: 56% of the total) (Histogram 4) hinges on the process of inference, interpretation and the search for new information.



There were few signs of movements of construction by direct assimilation and none of the category of 'sub assimilation'. Analysis of the messages also showed that during the students' interaction with each other or with their tutor, they were involved in a process of reflection. Their reflection focused on the following dimensions: the consistency of information, its implication as information and as a reasoning structure, and the limits of its use and interpretation. In fact, the analysis of the students' contributions show a predominance of the level 3 consciousness (65% of the total) (Histogram 5).



The students' different expressions of reflection point to skills that can be evaluated. Kuhn (1992) considers these a sign of argumentative thought. Moreover, we can make a correlation between these expressions and the three dimensions which define the process of argumentation (Marttunen, 1994):

- The analytical and assessable dimensions, expressed in the students' messages by a reflection based on the limitations, implications and consequences of a piece of information or knowledge.
- The critical dimension (of consistency) which in our analysis corresponds to the students' reflections on the consistency and universality of the information put forward by their peers.

The main elements of the argument present in the students' messages were opposition, the response to opposition and principles.

The reason for the limited signs of argumentation can be found in the very comments of the students during the semi-structured interview. In fact, the participants pointed out that using certain tools, like 'Forum' and 'Initiating Discussion' was relatively difficult for two main reasons. First of all, these tools force them to present the facts, and then to relate these facts to their conclusions. Secondly, they do not have sufficient knowledge[6] to construct an argument. Some participants also pointed out that peers tend to explain, even justify their positions. This aspect translates into a 'facility' for expressing opposition and disagreeing with the peers rather than constructing and defending their own opinions. It seems that because they were unable to master the ideas put forward in the case study, the students

tended towards the analysis, evaluation and criticism of the substance of the peer intervention.

Restructuring of knowledge

We examined the knowledge construction activity, the meta-cognitive reflections, the strategies and behaviour of the students relative to negotiation and argumentation. We then identified indices within the students' messages that led us to observe behaviours and actions that showed us that the students were engaged in a cognitive activity side-by-side with the processes of negotiation and argumentation. We also saw indications of a tendency in the students towards restructuring as the type of knowledge construction activity and meta-cognitive reflection. With respect to the this, we observed the presence of indices that conceptual change and cognitive conflict research (Mason and Santi, 1994, Chan et al., 1997) and research on the revision of the explanatory model (Hafner and Stuard, 1995) designates as elements that can stimulate restructuring and counter its obstacles. It is a matter of the subject being conscious of the cognitive structure which supports knowledge, not to mention the fact that the subject can become involved in processes of explanation, interpretation and inference about and following on from his own knowledge. This was verified by the nature of the explicit knowledge construction activity and by the level 3 Awareness.

Before presenting our analysis of the effects of the PMS on the process of flexible construction of information, we reiterate what we put forward about the concept of cognitive flexibility during the census of the written material. Relying on Spiro's theory of cognitive flexibility, we argued that flexible understanding depends on the subject being conscious that the relationships and conceptual links are a function of the totality of variables. The manipulation of which gives them the freedom to give and defend different viewpoints on a given piece of knowledge (Oubenaïssa, 2000). We said that in order to be able to conclude these operations, it is necessary for the subject to have some control over his cognitive structures. This view is supported by Spiro (1987), Spiro et al. (1991), and Jacobson and Spiro (1995). This control gives him the ability to subsequently transfer the meaning of his knowledge to new and different contexts. A subject who is conscious that the validity of his knowledge is limited (conception, representation, belief) is a subject who has a flexible understanding of the meaning of knowledge and who is, therefore, better able to transfer this knowledge.

Therefore, as a sign of the construction of flexible understanding, we have stated that the subject must have a degree of control over his cognitive structures and must demonstrate that he is capable of defending different viewpoints or defining the limits of validity of different views presented to him. During the analysis of the students' messages and by referring to the level of consciousness and to knowledge construction activity, we made certain observations that we summarise in Table 2.

Table 2: Contribution of the different analysis approaches to question of research related to skill of negotiation, argumentation, knowledge restructuring and to the concept of flexible comprehension.

		Analysis tools				
Flexible Comprehension	**Restructuring**	**Knowledge Construction Activity**	**Metacognitive Reflection Levels**	**Negotiation Behaviours**	**Communication Strategies related to Negotiation**	**Argumentation Elements and Criteria**
		Explicit Knowledge Construction : • Inferences. • Interpretation. • Research of a new information.	Awareness of methodological procedures in knowledge construction : • Degree of Consistency. • Degree of Limitations. • Degree of Plausibility. • Degree of Generalizability.			

	Negotiation			Integrative Behaviours • Compromising. • Confirming. • Agreement. Descriptive Behaviours • Task-Oriented Question. • Task-Oriented Description.	Communication Strategies • Argument assertion. • Question. • Counter support Statement. • Concession.	Desintegrative Behaviours Confronting • Critics. • Attacks.
Argumentation			Awareness of methodological procedures in knowledge construction • Analysis and evaluation : limitations, consequences implications, methodological procedure in knowledge constr	Desintegrative Behaviours Confronting : • Critics. • Attacks. Disagreement: • Direct Disagreement.	Communication Strategies • Argumentation Assertion. • Question.	Argument Elements : • Opposition • Response to opposition • Warrants. • Data. • Claims.

		uction. • Critics : consistency, plausibility.			

On the subject of flexible understanding, we prefer to talk about prospective indices since no test was submitted to the students to test their understanding, even if we do not deal here with understanding as the goal of a learning objective, but rather as the process that directs knowledge construction. We can however say that we have at our disposal two principal elements that can, in our opinion, promote flexible understanding. The first is the context and the dynamic of the students' interaction with the information that involves them in a simultaneous process of negotiation and argumentation. The second is the involvement of the students in a constant process of analysis and evaluation. It must be pointed out that for one and a half hours while the students tried to resolve the problem presented in the case study, their discussion and interaction with each other was mainly centred on the analysis and identification of the problem. During the semi-structured interviews which followed, the students stressed the fact that they did not have enough time to reply to questions in the case study and that they had been surprised by the different responses to the one question, "What is the problem?".

We cannot say, however, that what we observed in the students (ie. the manifestation of the processes of negotiation and argumentation and the signs favourable to restructuring and to flexible understanding), is the direct result of the students' interaction with the PMS prototype. But, it seems that the cognitive tools of the PMS had an effect on the behaviour and actions of the students. This can be inferred from the results of the analysis of the semi-structured interview and the tapes of the verbal protocols that we set out below.

Three elements stood out in the analysis of the semi-structured interview:

- The students stated that the tools on offer had a big effect on their learning process and the way in which they did the case study.
- The students pointed out that they were forced to be more explicit, more systematic and were made more conscious of the complexity of the case study because of the format of the tools and because of the exchange modalities brought on by their use of the tools.
- The students made it clear that the simultaneous interaction with their peers and with the trainer and the interaction with the format of the tools, especially 'Forum', Problem-Solving', 'Analysis' led them to :
    - argue and give opinions.
    - analyse, evaluate and self-evaluate.
    - construct, readjust and refine their understanding.

For the students, interacting with the environment's tools stimulates, activates or allows a larger cognitive involvement in the accomplishment of the task. According to them, using these tools made them analyse and evaluate the validity and pertinence of their peers'

contributions. They also became more conscious and more critical when faced with their peers' contributions. They stated that they were confronted with opinions, explanations, affirmations and very few arguments.

The students also made it clear that the process of interaction made them aware of the construction of an understanding which took into account the complexity of the problems and which integrated the different ways in which the students gave their opinions. It appears also that understanding is built in parallel with the processes of analysis, evaluation and data restructuring. It is important to note that we were not only looking at the results of the verbal protocol, but that we paid particular attention to the actions of the students and to the processes implicit in these actions.

The results of the analysis of the verbal protocol back up the data received from the semi-structured interview concerning the involvement of the students in a process that is more critical (analysis and evaluation) of the information conveyed by their peers. It appears that the cognitive tools associated with the PMS institute an exchange and communication dynamic which uses the format of the tools and the different modes of interaction that come with it to co-ordinate, anticipate and plan out the interaction. As several students pointed out, the different tools are used in precise contexts to respond to specific needs and expectations, and at particular stages of the learning process.

The pedagogical principles which worked best when looking for signs of the construction of a flexible understanding of information seem to indicate that a context which reconciles the elements of restructuring, negotiation and argumentation is a context which also stimulates flexible understanding.

It appears also that making a range of different tools available to the students permitting various exchanges appears to allow the promotion of the processes of negotiation, argumentation, restructuring and the construction of a flexible understanding. Examples of the tools and associated processes were:

- Informal: 'Question/Answer' tool
- Explanatory: 'Ask Explanation', 'Problem-Solving Approach ' and

  "Present Analysis' tools.

- Justification: 'Forum', ‘Start Discussion' and 'Present Analysis' tools

With regards to the pedagogical principles integrated into the PMS that had a positive impact on these processes, we found two tendencies. One that seems to be related to the diversity of the exchange and interaction modalities and another related more to the presence of the cognitive tools. In order to create diverse exchange and interaction modalities, we created tools whose format and functionality speak to a large group of pedagogical principles. Each PMS tool reflects a combination of more than one pedagogical principle which calls upon the pedagogical communication of information, upon social interaction, data processing, the construction of new knowledge and upon meta-cognitive processes.

When we designed the tools, we relied mainly on those pedagogical strategies that would allow the activation and facilitation of the process of negotiation, argumentation and restructuring. We wanted to place tools at the students' disposal that would put them in a context of problem solving, position making, anticipation and planning. By ensuring that the students' interaction with the PMS tools was in an authentic context of problem-solving, we saw that the tools, as well as allowing these transactions to take place, shaped the exchanges of the students and the way in which they resolved the case study. By analysing

the verbal protocols and the student's comments we were able to verify the extent to which the PMS tools promoted the involvement of the students in processes such as problem-solving, decision-making and position making. Effectively, Hafner and Stewart (1995) consider these elements as the motor of the process of argumentation and restructuring.

We also witnessed how the juxtaposition of two types of tools with different functionality, structures and demands, allows the coordination of distinct processes. The first, more formal, analytical and systematic (eg. the 'Forum', 'Start Discussion', 'Give Analysis', 'Problem-Solving Approach' tools), is important for the process of argumentation and restructuring. The second, more informal ('Question/Answer'), allows peers to express themselves and confronts the students with distinct contributions and formulations (Oubenaïssa, 2000). This seems to have led the subjects to distinguish between opinion, explanation, and justification and has made them aware of the diverse viewpoints surrounding a given understanding. In relation to this process, the 'Question/Answer' tool is very important because, according to the students, despite the poor quality of the messages that it elicits, it allows them to construct a progressive, flexible and complex understanding of the problem being analysed. The students stated that the impact of the 'Question/Answer' tool differs depending on the state of their progression. They also stated that, throughout the interaction, this tool, though not very systematic, allowed them to make exchanges and to follow the growth of the others students' understanding. In their opinion, the fact that the 'Question/Answer' tool was not very "structured" allowed for a quick and undemanding interaction during the composition of messages.

It appears that the cognitive tools that reconcile the diversity and rapidity of interaction with the conceptual representation of the current learning task have a positive effect on the flexible understanding of information as well as on the complex skills of negotiation, argumentation, and the restructuring of knowledge.

In the testing of the PMS prototype, we used the information to promote the cognitive involvement of the students in the activities of negotiation, argumentation, restructuring and the construction of flexible understanding. However, there was no element that could establish a direct relationship between what we observed and the effect of the students' interaction with the PMS on the manifestation of their behaviour and actions.

Nevertheless, during the interviews, the students used terms to do with stimulation, curiosity, incitement etc. to talk about elements that related to the effects of their interaction with the PMS tools. These related to the cognitive level (analysis, evaluation and comparison) as well as to the motivational and socio-affective level.

The students also talked spontaneously about the impact of the PMS tools on their learning process by making reference to:

- The impact of the tools on the formulation of messages;
- The effect of the process of research and data processing;
- Their interaction in the process of understanding and knowledge construction and the refinement of these processes;
- The impact on their perception and interaction with each other;
- The effect of feedback on their styles and learning process.

These notions were expressed spontaneously by the students without being explicitly suggested or induced by the interview questions. When the students were asked to respond to several questions related to their appreciation and perception of the environment, we placed the verbs into two categories (Table 3).

Table 3 : Facts raised by students during semi-structured interview on the effects of the PMS' cognitive tools on the processes of learning and interaction.

	Verbs used to express	
Actions initiated by the learner.	Related to more individual cognitive skill such: knowledge restructuring.	Related to more socio-cognitive and metacognitive skills such: negotiation and argumentation.
	create, built, think, delimit, develop, revise, come back, actualise, refine, elaborate, put forward.	Analyse, verify, compare, evaluate, pronounce, argue, pronounce, develop, discuss, etc.
Environments effects on learners' actions.	Structure, facilitate, help, allow, oblige, stimulate, push, direct, incite, lead to, made possible.	

We viewed this as more evidence that the PMS tools contributed to the activation and stimulation of the cognitive processes in question.

The research aims of this study deal with cognitive processes in relation to the restructuring, negotiation, argumentation and knowledge construction of a group of learners during their interaction with several cognitive tools. The methods we used to collect the data, the analysis tools we chose for this research, as well as the descriptive approach we adopted, allowed us to observe and describe the actions and behaviour of the subjects in relation to the learning activity during the testing of the PMS prototype.

Discussion and Conclusions

The University students who took part in the trial of the prototype took on the role of experts within the parameters of the research and expressed an opinion on the quality and pertinence of the prototype in terms of its impact on the learning process and on knowledge construction. Since our aim was not to verify the achievement of the learning objectives but rather to observe how the activity and the learning process manifested themselves, we did not attempt to summarise or evaluate the results. We analyse only the content of the messages composed by the students in terms of actions and cognitive activity. The analysis of the students' messages, comments and reflections, led us to certain conclusions about the quality and pertinence of the context as well as about the dynamic of the learning process. This research shows that by putting simple cognitive tools at the disposal of learners, we can generate high-order learning products[7] similar to those outlined in the results of the study on CSILE's[8], VLC and GSLC[9], KIE[10], Model It[11], MediaMOO[12] etc.

In our opinion, it is the learner's interaction with the cognitive tools and not the structure of the environment or the array of manipulation tools on offer that promotes high order cognitive activities. As a result, it is necessary to concentrate more on the conception and design of cognitive tools based on pedagogical principles of design, rather than spending time on the architecture of the environment by offering all sorts of technological options.

When we analysed the students' messages, the tools we chose allowed us to describe the different actions and behaviour exhibited by the participants and to find out to what extent cognitive tools could promote them. It is difficult to say if the use of different analytical tools affected our analysis, even though these tools were supported by the same processes (negotiation behaviour, negotiation strategies, argumentation, meta-cognitive reflection) and were all aimed at describing and distinguishing interdependent processes. It should be noted that the results of our analysis converge with other research (Marttunen, 1994; Mason and Santi, 1994, Cohen and Scardamalia, 1998). Our research as well as many others underline the relationships that exist between meta-cognitive reflection and learner's involvement in the process of argumentation and the relationships that exist between the behaviours observed and the strategies used.

The large amount of pertinent data gathered during our research, however, leads us to stress the importance of undertaking other research along the same lines. It is our opinion that there remains much to be done with respect to the methods used to analyse cognitive activities and the effect of cognitive tools in mediated and distributed environments. Moreover, we feel it is important that we have research that is not limited, as in the present case, to interviews and questionnaires focussed on the pertinence and quality of these types of interaction. We need to develop analytical tools that will allow the researcher to make findings on the quality of the interaction and on the cognitive involvement of the participant by making reference to well-identified skills.

Many pieces of research in education have looked at the theory of cognitive flexibility. The approaches adopted in these research studies content themselves with applying Spiro's recommendations that, although they challenge the impact of representations on the transfer, remain largely concerned with the organisation of content. It would be interesting to see and compare what one could observe about transfer, by using tools such as those in the PMS, on a content of uncertain nature and organisation. According to Voss (1992), transfer is dependent upon the context of interaction and appropriation of information. We observed during our own analysis of the semi-structured interviews that several participants pointed to the construction of a flexible understanding and an expansion of the mind that resulted from the modalities and modes of interaction.

In fact, our research subscribes to the notion that the aim of qualitative research is to arrive at an understanding by observation and analysis, rather than to draw conclusions by simply testing. We hope that this research report will promote a type of research more concerned with the pedagogical mediation of new learning environments and not just their mediatisation. We also hope that, henceforth, cognitive tools will be more prominent in the interface and structure of these environments so that processes related to the development of high order skills can be generated, stimulated and managed.

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