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Conditional Reasoning: A Key to Assessing Computer-based Knowledge-building Communication Processes

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Abstract: This article describes a methodological approach to conditional reasoning in online asynchronous learning environments such as Virtual-U VGroups, developed by SFU, BC, Canada, consistent with the notion of meaning implication: If part of a meaning C is embedded in B and a part of a meaning B is embedded in A, then A implies C in terms of meaning [Piaget 91]. A new transcript analysis technique was developed to assess the flows of conditional meaning implications and to identify the occurrence of hypotheses and connections among them in two human science graduate mixed-mode online courses offered in the summer/spring session of 1997 by SFU. Flows of conditional meaning implications were confronted with Virtual-U VGroups threads and results of the two courses were compared. Findings suggest that Virtual-U VGroups is a knowledge-building environment although the tree-like Virtual-U VGroups threads should be transformed into neuronal-like threads. Findings also suggest that formulating hypotheses together triggers a collaboratively problem-solving process that scaffolds knowledge-building in asynchronous learning environments: A pedagogical technique and an built-in tool for formulating hypotheses together are proposed.

Key Words: knowledge-building, collaborative learning, transcript analysis, conditional reasoning, meaning implication, Piagetian theory.

Category: K.3, K.3.1, K.3.2, K.3.m, J.4.

1 Introduction

Conditional reasoning seems to be a key component of knowledge-building communication processes established between learners in asynchronous learning networks such as Virtual-U V-Groups. Virtual-U is one of the beacon technologies developed by the Telelearning Network of Centres of Excellence. It was created at Simon Fraser University, British Columbia, Canada, and is being permanently implemented through the delivery of new versions.

With this approach, conditional reasoning is assessed by identifying the flows of conditional meaning implications in online discourses. Different from statements (which are written accounts of facts or beliefs recognized as truths by the users), conditional sentences open the symbolic universes of users' online discourse to the possible and the necessary. The possible and the necessary are the raw material for creating novelties, formulating hypotheses, thinking upon them, and problem solving. Conditional sentences create online discourse situations in which the learners' collaboration is promoted by challenging interpretations of facts and beliefs exposed

in statements and by looking for solutions for the problems posed by the inconsistency and/or discordance of previously exposed facts and beliefs.

The flow of conditional meaning implications across online discourse, assessed by transcribing users' dialogues, suggests that conditional reasoning scaffolds the collaborative symbolic exchange of meanings. Conditional reasoning also seems to be one of the most important scaffolds for knowledge-building because it promotes the reorganization of the users' and groups' semiotic configurations [Campos 96b].

2 Theoretical Foundations

Our methodological approach to computer-based knowledge-building communication processes derives both from the Piagetian model of knowledge [Piaget 91] [Piaget 77a] [Piaget 76b] [Piaget 76c] [Piaget 50] [Ramozzi-Chiarottino 97] [Ramozzi-Chiarottino 88] and Popper's conceptualization of worlds 1, 2, and 3 [Popper 94].

According to the Piagetian model, inference results as the gist of the process of cognition. Based on this model, we hypothesized that conditional reasoning is at the core of learners' cognition processes. An appropriate transcript analysis technique was thus developed in order to verify whether conditionals were the link to reasoning. We considered the transcriptions of computer mediated educational objects of knowledge, products of mental processes [Popper 94].

2.1 Merging Piaget and Popper

In spite of the extraordinary contribution of Jean Piaget to science and philosophy, his works did not directly address the problem of communication. Communication is as central to understand the learning process as cognition. Piaget's model of knowledge contributes to the understanding of the possibility of knowledge acquisition but not to the understanding of knowledge itself. The necessary organic constraints actualized by the various forms of inference - deduction, causality, and meaning implication - [Ramozzi-Chiarottino 97] open the way to the possible in concrete action and also in representation.

Popper also did not directly address the problem of communication, but his contribution to the understanding of the problem of objective and subjective knowledge through his Three Worlds proposal allows the conceptualization of objects of knowledge. According to Popper, World One is that of physical objects and physical states; World Two is that of mental states, of mental conscious experiences (related to the problem of the body-mind interaction); and World Three is that of the products of the human mind, or theories [Popper 94].

It could be argued that merging Piaget's and Popper's ideas is neither easy nor straightforward. Indeed, Piaget and Popper dealt with different subjects from different perspectives although both put biology at the center of their works. The former was engaged with an ambitious proposition of a scientific epistemology based on biology, in which virtual models from a radical interactionist viewpoint are conceptualized to be verified through empirical research. The latter was a critical rationalist [Kesselring

97] mostly concerned with the problem of truth and scientific knowledge. However, there is more convergence than divergence between the thinkers.

The most remarkable difference seems to be Popper's late conversion to Darwinism [Popper 87] and Piaget's insistent refusal in accepting it completely. Piaget never explicitly accepted the realistic viewpoint in the Genetic Epistemology [Kesselring 97]. Popper's acceptance of Mayr's idea of open behavioral programs shows that he was aware that not all behaviors are programmed. Some of them are open, i.e. when organisms - even driven by the necessary characteristic of genetic constraints - have ways to deal with the possible posed by the challenges of the external world.

Piaget also changed. His *in media res* initial understanding of interaction (where exogenous and endogenous processes played equal roles in adaptation in the search for equilibrium) was reformulated in the last decades of his life to include the idea that some genetic processes were completely pre-determined in terms of possibility, depending on the environment to actualize them [Piaget 92].

We argue that working from the Piagetian virtual model of knowledge by merging his and Popper's contributions to science and assessing the actualization of the possibilities envisaged by evaluating concrete results of produced knowledge is to advance communication theory to new perspectives.

2.2 Communication, "Schematizations", and Semiotic Configurations

The possibility of knowledge can only be achieved through and by communication. *Homo Sapiens*, as a species, developed a specific way to interact with the world. It is a symbolic interaction through language that inspired Cassirer to call the human being a *Homo Symbolicum* instead of *Homo Rationale* [Cassirer 94].

According to Piaget, this symbolic interaction is propitiated by a hypothetical semiotic function that allows the constitution of a virtual world of representations [Piaget 76a]. The semiotic function develops from action and emerges when the child shows the capacity to speak, after having achieved the permanence of the object [Piaget 77b]. Throughout her/his life, the child constructs the possibility of knowledge through action, but mediated by language after the sensory-motor period.

The possibility of communication follows the same way: through actions during the sensory-motor period and through natural language after its achievement [Campos 96a]. Communication is a social mechanism based upon organic constraints from which the human species became able to evolve and upon which survival depends [Waddington 63].

Natural language is the raw material of communication. It follows some rules in its use but although these rules are made possible due to previous organic necessary constraints, natural language is essentially contingent - dealing with referents instead of objects - and is related to the culture of the social groups in which it is exercised.

Jean-Blaise Grize's formulation of the verbal communication process is a fundamental and extraordinary advance if compared to most theories of social communication because it departs from Piaget's Genetic Epistemology adding the

unveiling of the working scheme of the relative independence of the symbolic dimension of the human species.

From Grize's scheme it can be argued that knowledge is built into the process of communication and that it is from this process that natural language emerges producing the possibility of formulating notions, and from notions, concepts. We can talk, thus, of notional and conceptual knowledge. Concepts are signs related to definitions (axioms), and are well defined objects of models. Conceptual knowledge is structural and scientific. Notions are signs related to referents (cultural). Notional knowledge is fluid and consensual. Notional knowledge is broader than conceptual as the second results from the first when a person is engaged in the construction of closed structures of well-defined objects. Conceptual knowledge is not possible at all without notional knowledge. Nevertheless, conceptual knowledge is built from natural language and needs natural language to formulate it [Grize 90].

Piaget always pointed to the fact that conceptualization is a process [Piaget 74]. Grize's contribution makes it possible to amend Piaget by saying that conceptualization is a process of notion refinement. From notions, different levels of concepts can be constructed - from the weakest (as the concept of democracy in social sciences), to the strongest (as the concept of triangle in geometry).

Grize understands verbal communication as a "schematization", a process of building and rebuilding of notions formulated through natural language. The idea of having senders and receivers loses its meaning in a "schematization" as the notional virtual space of a sender always implies the building of an image of the receiver in such a way that the built notion makes possible the rebuilding of it by the receiver because messages can only be understood as communicated if and only if interpreted according to the working play of the representational symbolic schemes of both.

This ever-changing process of symbolic exchange is made possible by the mechanism of communication. It occurs in virtual spaces - or symbolic places - in which participants build their verbal representations [Grize 90]. Grize's conceptualization can be applied to other communication dimensions of knowledge through the notion of semiotic configurations [Campos 96b].

Semiotic configurations are ever changing notional virtual spaces built and rebuilt by participants engaged in a communication process in which not only the verbal dimension of human representation is exercised but also the perceptual dimension. Both verbal and perceptual dimensions are coordinated synchronically by cognition and emotions which have in their core, in turn, the unique human ability to infer from virtual symbolic representations as opposed to most other animal species which are also able to infer but only causally from their actions. Elsewhere, we verified the role of semiotic configurations in the evolution of the communication relationship between the child and television through a longitudinal study in which Brazilian children of various ages were clinically observed over a period of almost three years [Campos 96a] [Campos 96b].

Semiotic configurations allow us not only to analyze communication processes mediated by television but also those mediated by press, radio, movies, and computers. Although it is not possible to access mental processes directly (and that is why Piaget developed the clinical observation technique), we argue that the content of media products such as newspapers, magazines, movies, television programming and

transcriptions of computer-based communication are objects of knowledge as they are concrete results of the dynamic play of intersections of various semiotic configurations.

These objects of knowledge are an empirical actualization of those mental processes in which semiotic configurations are permanently built and rebuilt, expanding and shrinking, according to the person's lifetime since it is well-known that neuronal abilities increase or decrease depending on age. Those objects of knowledge are products of the mind, are part of World Three and being such, they are privileged data from which models can be verified.

2.3 Conditional Reasoning and Meaning Implication

Conditional reasoning is one of the cornerstones of the inferential process according to Piaget [Piaget 50]. The form of hypothesis is the expression of the main characteristic of human thinking. Hypotheses are "*If...then*" operations and generating them supposes conditional reasoning, and thus inference.

According to logic, the statement "if P then Q" will only be false in the case that the antecedent P is true and the consequent Q is false. The fact that sometimes people reason according to the truth-functional logic but that most of the time they do not has puzzled psychologists.

Several research programs were developed by scientists working either from the neopiagetian or other theoretical perspectives. Indeed, the problem seems to be so obscure that even so-called Piagetians have been struggling against windmills that never stop turning. It is beyond the scope of this article to make a review of the literature on conditional reasoning; however, a number of remarks and indications of important positions are necessary.

Research on conditional reasoning is contradictory because studies fail to make the distinction between notional and conceptual knowledge. It is also contradictory because few scientists really understand that Piaget proposed a model of knowledge in which not the actual is empirically established but the virtual [Ramozzi-Chiarottino 97] by carefully characterizing what is necessary and what is possible in the human experience, well in accord with his openly-declared Kantian affiliation [Piaget 59] [Piattelli-Palmarini 80].

Furthermore, Piaget insisted that he was *not* a psychologist and that his psychological research was a *by-product* of his epistemological theory [Piaget 83]. From Piaget's theoretical viewpoint it is therefore useless, for example, to test hundreds or even thousands of formal operative subjects to find out whether most of them think according to the rules of truth-functional logic. As Piaget talks about the *possibility* of the human species at arriving a full logical thinking, only one subject is enough to validate his theory.

Indeed, this lack of understanding produced a number of empirical studies on conditional reasoning by psychologists that, although propitiating a valid contribution to empiricist psychology, are not consistent at all with Piaget's theory.

Furthermore, most of those studies work with the idea of entailment, which is an attempt to mix form and content up in order understand the role of meanings in human

reasoning. Unfortunately, this research produced only contradictory and puzzling results as it is not possible at all to explain cognitive necessity by necessary discourse systems.

Discourse systems are conceptual structures that may have various levels of closure depending of the nature of the concepts (weak or strong). The notion of meaning implication was formulated by Piaget precisely to solve this paradoxical situation. Piaget defined meaning implication in several ways:

- as a link between *predicative* meanings and not between propositions [Piaget 76b];

- as the *source* of necessary relations considering that there is meaning implication in its elementary form between two schemes *x* and *y* when *x* implies *y* considering that the meaning of *y* is part of or has something in common with that of *x* [Piaget 77a];

- as a relation among meanings which is transitive and that has *various degrees*, meanings being local, systemic or structural [Piaget 91].

Piaget's definitions, however, have led to a number of misunderstandings [Lourenço 95] [Garcia 91] [Piéraut-Le Bonniec 90] [Ricco 90]. From our viewpoint, meaning implication is the inferential building and rebuilding of meanings as opposed to material implication. Hegenberg came close to this understanding, but as he dealt with scientific knowledge, conceptual meanings were subordinated to formal logical reasoning in his explanation of what meaning implication really is [Hegenberg 91].

The notion of meaning implication challenges some established ideas about constructivism and the role of meanings in the human experience because it is the *source* of necessity. Being the *source* means that meaning implication is crucial for the constitution of the various possible levels of necessity found in conceptual structures, but it is *not* necessary itself. Its constitution is essentially contingent. We argue that natural conditional reasoning is normally driven by meaning implications since daily life experience is notional.

Something quite apart is formal conditional reasoning. In this case, material implications apply. Material implications can only be found in products of knowledge such as logic or other conceptual constructions in the strongest sense as those in the weakest sense usually do not fill up all requirements of necessity and sufficiency.

Because models are necessary structures and scientific theories are conceptual models of whatever empirical reality or possibility of empirical reality (as in the case of Piaget), necessity can then be found in its higher level after a process of refinement of concepts, built from meaning implications among notions. Hypotheses can be built in both cases, in any manner whatsoever, as they can be constructed by using notions as well as concepts.

Piaget unfortunately died precisely when the idea of meaning implication was being developed. Furthermore, Piaget, himself, plays a part in this huge misunderstanding because although pointing out that he considered that a logic of meanings would be a natural and necessary extension of his operatory logic, he was mainly concerned with cognitive aspects of development and not with communication at all.

The kingdom of natural language and contingency was not something that particularly attracted Piaget as his works reveal. This task was later developed by his closest collaborator on logic, Jean-Blaise Grize, in the *Centre des Recherches Semiologiques* at the University of Nêuchatel, in Switzerland.

It is instructive to remember that Piaget stated clearly that his last research on meaning implications was developed *"at the level of actions rather than of statements"* [see Piaget 91] (page 121). In other words, in his last research Piaget did not take into account the building and rebuilding of meanings in the production of sense, but its role in cognitive development.

It is not surprising to find that most of the research by "Piagetian" or neopiagetian psychologists was done by applying results from research on actions but taking logical statements as their focus. Thus, these conclusions were inconsistent with Piaget's virtual model of knowledge.

Most studies on conditional reasoning are inconsistent with the late development of the Piagetian theory and ignore Grize's contemporary contribution to it. Some studies indicate that entailment is more important than familiarity with content in conditional reasoning [Lourenço 95] [Ward, Byrnes and Overton 90]. Others indicate the opposite by arguing that either context, familiarity and concrete content [Thompson 94] [Markovits and Vachon 90] [Markovits 86] or training [Overton, Byrnes and O'Brien 85] [O'Brien and Overton 82] [O'Brien and Overton 80] increase conditional reasoning performances. Scholnick, in a study about three "faces" of *If-Then* (propositional, semantic and presuppositional), included Piaget's theory in the propositional "face" [Scholnick 90], something done also by Keating [Keating 90], and totally ignoring the late developments of the theory.

The contradictory findings and erroneous analysis can be solved by applying the distinction between *material implication*, which is a formal necessary operation among conceptual objects, and *meaning implication*, which is a notional contingent relation among cultural referents. Appending Grize's double contribution to the communication and Piagetian theories seems to be unavoidable.

3 Research

3.1 Objectives

We hypothesized that the inferential process of the mind in online asynchronous learning environments such as Virtual-U VGroups could be identified by following the flow of conditional meaning implications throughout the courses. We say "conditional" meaning implication because meaning implications can also link other logical forms such as "and" (conjunctive), "either...or" (disjunctive), can be negative or affirmative, and can also be founded in pure word plays such as those found in literature and poetry (being metaphorical, poetic, and the like).

We also hypothesized that the flow of conditional meaning implications would scaffold knowledge-building as an intentional learning process [Scardamalia and Bereiter 94] [Bereiter and Scardamalia 93] since it is consistent with the notions of idea generation, linking and structuring [Harasim 93] [Harasim 90].

To achieve these goals we studied two Virtual-U online courses offered in the summer session of 1997 by Simon Fraser University, Vancouver-Burnaby, BC.

3.2 Courses Studied

VGroups online transcriptions of two mixed-mode Simon Fraser University human sciences graduate courses were studied. Mixed-mode are courses that are taught both online and face-to-face. The first was a Communication course. The second was an English course.

3.2.1 General Information on the Communication Course

The course was offered in the winter/spring session of 1997. Seven people were involved in the course: the instructor responsible for it, another instructor who was invited to participate and five graduate students from different departments (Communication, Computer Science, and Education). One of the students - a researcher - participated only partially.

The course was designed to have 12 conferencing spaces. Ten conferencing spaces were supposed to take place in consecutive defined periods while the others would be open for participation during the whole course. Participants wrote 389 messages.

3.2.2 General Information on the English Course

The course was offered in the winter/spring session of 1997. Six people were involved in the course: the instructor responsible for it, a researcher invited to participate in order to help deal with the software and four graduate students.

The course had 6 conferencing spaces, designed to take place throughout the whole course. Participants wrote 149 messages.

3.3 Procedure

The first step consisted of sorting out all messages of all conferences of both courses by date and renumbering them accordingly. Virtual-U VGroups software does not have this feature; it only sorts out and numbers messages by date per conference, and not per course. Besides sorting them by date per conference, Virtual-U VGroups also sorts out messages by reverse-date, by author and by thread per conference.

The second step consisted of identifying conditional sentences in the messages by looking for words usually related to conditional reasoning such as “if”, “might”, “would”, “could”, “found”, “whether”, “maybe”, “perhaps”, etc. Conditional sentences or groups of sentences organized as arguments were considered by analyzing their contextual meaning in order to establish if the occurrence of the

conditional words really indicated that conditional reasoning was under way. All conditional sentences or group of sentences were marked in all messages of both courses studied. We considered the messages the units of analysis.

A number of messages with different subjects were subdivided accordingly. In other words, if in a given message (X) the user built a number of conditional sentences or arguments, three for example, and all of them dealt with different subjects, i.e. A, B and C, then they would be grouped in three different subdivisions according to the contextual meaning, such as X-A, X-B, and X-C.

Furthermore, the character of each conditional sentence or group of sentences organized as arguments was identified using the following description: necessary and sufficient; necessary and not sufficient, and just possible. It must be clearly stated here that we **did not** attribute necessity and sufficiency from the viewpoint of formal logic. Our instrumental definitions for those notions are as follows:

- necessary and sufficient - what cannot be otherwise and whose conclusions are definitely contained in the premises;

- necessary and not sufficient - what cannot be otherwise but whose premises do not fully support the conclusion, opening way to doubt and possibilities;

- possible - what can be otherwise.

The third step consisted of establishing what the core meaning of a given conditional sentence or group of sentences organized in arguments was, by choosing either a key word or key sentence depending on each case. Then, the building and rebuilding of meanings from one message to the others were followed chronologically. The route followed by meanings that were built and rebuilt in the messages along the courses was called flow of conditional meaning implications or "*meaning implication thread*".

The fourth step consisted of comparing meaning implication threads and Virtual-U VGroups threads. VGroups threads are built by users by replying to messages using a "reply" bottom in the desktop. The feature consists of creating a kind of tree where branches are built by connecting replied messages to the ones that originated them. When a user writes a message but does not reply to anybody, a new original tree is created. Then, other users can continue it, creating a thread, by appending replies to the original message and to those that follow it.

The fifth step consisted of identifying hypotheses across the conferences of the courses studied and verifying whether they were built collaboratively or not, through text analysis.

3.4 Results

3.4.1 The Communication Course

From the 389 messages posted during the course, 261 presented conditional reasoning. The frequency of messages indicating the occurrence of conditional reasoning was 67.1% of the total number of messages [Tab.1].

Very few messages presenting necessary reasoning - sufficient or not - occurred in the Communication course. Most messages presented possible conditional reasoning [Tab.2].

MESSAGES	NUMBER	FREQUENCY
With conditional reasoning	261	67.1
Without conditional reasoning	128	32.9
TOTAL	389	100

Table 1: Occurrence of conditional reasoning in the messages (Communication course)

MESSAGES WITH	NUMBER	FREQUENCY
Necessary and sufficient arguments	7	2.7
Necessary and not sufficient arguments	8	3.1
Possible arguments	246	94.2
TOTAL	261	100

Table 2: Occurrence of messages with necessity, sufficiency and possibility in conditional reasoning (Communication course)

MESSAGES WITH MEANING IMPLICATIONS	NUMBER	FREQUENCY
Total coincidence between meaning implication and V-U VGroups threads	112	39.2
Partial coincidence between meaning implication and V-U VGroups threads	76	26.6
Connection with V-U VGroups threads only	26	9.1
Connection with meaning implication threads only	55	19.2
No connection with both V-U VGroups and meaning implication threads	17	5.9
TOTAL	286	100

Table 3: Occurrence of messages and sub-messages with meaning implications and their connections with V-U VGroups and meaning implication threads (Communication course)

MESSAGES WITH MEANING IMPLICATIONS	NUMBER	FREQUENCY
Connected to meaning implication threads occurring in the same conference	212	74.1
Connected to meaning implication threads linking different conferences	27	9.5
Connected to meaning implication threads linking class statements with a given conference	2	0.7
Disconnected to meaning implication threads	45	15.7
TOTAL	286	100

Table 4: Messages and sub-messages with meaning implications and their connections with meaning implications threads in the conferences (Communication course)

Some of the 261 messages with more than one conditional reasoning sentences presenting different subjects were subdivided into sub-messages. The result of this operation was 286 messages and sub-messages with conditional meaning implications. We compared the flow of conditional meaning implications to Virtual-U VGroups threads.

Results indicate that most of those 286 messages and sub-messages were part of conditional meaning implication threads that coincided totally or partially with VGroups threads. In the first case, origin and destination of messages were exactly the same in meaning implication and VGroups threads. In the second case, origin of messages pertaining to a meaning implication thread was different, although the destination was the same [Tab.3].

The remaining messages occurred when conditional meaning implications were not linked to any other in a given meaning implication thread but were the destination of a specific VGroups thread connection; when conditional meaning implications were part of a meaning implication thread but were not part of a VGroups thread; and when conditional meaning implications were not part of both meaning implication and VGroups threads [Tab.3].

The flow of meaning implications occurred mainly within the same conference. But a number of messages with meaning implications was responsible for linking different conferences. Few messages produced in conferences connected to flows built from class statements occurred. There was also the occurrence of a significant number of messages isolated in different conferences, disconnected to flows [Tab.4].

3.4.1.1 Hypotheses

Users formulated hypotheses in approximately one third of the 286 messages and sub-messages with conditional meaning implications.

Most of the formulated hypotheses occurred in messages and sub-messages that were part of conditional meaning implication threads that coincided totally or partially with the VGroups threads.

Few hypotheses were found when conditional meaning implications were part of a meaning implication thread but not part of a VGroups thread.

No hypotheses were found when conditional meaning implications were not part of a meaning implication thread but were part of a VGroups thread; and when messages were not part of both meaning implication and VGroups threads [Tab.5].

HYPOTHESES	NUMBER	FREQUENCY	FREQUENCY IN THE COURSE
In messages in which there is total coincidence between meaning implication and V-U VGroups threads	67	70.5	23.4
In messages in which there is partial coincidence between meaning implication and V-U VGroups threads	24	25.3	8.4
In messages in which there is connection with meaning implication threads only	4	4.2	1.4
In messages in which there is: ● connection with V-U VGroups threads only ● no connection with both V-U VGroups and meaning implication threads	0	0	66.8
TOTAL	95	100	100

Table 5: Occurrence of hypotheses (Communication course)

3.4.2 The English Course

The English course had 149 messages. From those messages, 129 presented conditional reasoning. The frequency of messages indicating the occurrence of conditional reasoning was 86.6% of the total number of messages [Tab.6].

Very few messages presenting necessary reasoning - sufficient or not - occurred in the English course. Most messages presented possible conditional reasoning [Tab.7].

A number of the 129 messages with more than one conditional reasoning sentence dealing with different subjects was subdivided. The result of this operation was 180 messages and sub-messages with conditional meaning implications. We compared the flow of conditional meaning implications to Virtual-U VGroups threads.

Results indicate that most of the messages and sub-messages with conditional meaning implications were part of meaning implication threads and had no connection to VGroups threads [Tab.8].

Few messages and sub-messages were part of conditional meaning implication threads that coincided totally or partially with Virtual-U VGroups threads; and when conditional meaning implications were not part of a meaning implication thread but were part of a VGroups thread [Tab.8].

An important number of messages that was not part of either meaning implication or VGroups threads also occurred in the English course [Tab.8].

MESSAGES	NUMBER	FREQUENCY
With conditional reasoning	129	86.6
Without conditional reasoning	20	13.4
TOTAL	149	100

Table 6: Occurrence of conditional reasoning in the messages (English course)

MESSAGES WITH	NUMBER	FREQUENCY
Necessary and sufficient arguments	2	1.6
Necessary and not sufficient arguments	4	3.1
Possible arguments	123	95.3
TOTAL	129	100

Table 7: Occurrence of messages with necessity, sufficiency and possibility in conditional reasoning (English course)

MESSAGES WITH MEANING IMPLICATIONS	NUMBER	FREQUENCY
Total coincidence between meaning implication and V-U VGroups threads	11	6.1
Partial coincidence between meaning implication and V-U VGroups threads	2	1.2
Connection with V-U VGroups threads only	3	1.7
Connection with meaning implication threads only	115	63.8
No connection with both V-U VGroups and meaning implication threads	49	27.2
TOTAL	180	100

Table 8: Occurrence of messages and sub-messages with meaning implications and their connections with V-U VGroups and meaning implication threads (English course)

MESSAGES WITH MEANING IMPLICATIONS	NUMBER	FREQUENCY
Connected to meaning implication threads occurring in the same conference	92	51.1
Connected to meaning implication threads linking different conferences	34	18.9
Connected to meaning implication threads linking class statements with a given conference	4	2.2
Disconnected to meaning implication threads	50	27.8
TOTAL	180	100

Table 9: Messages and sub-messages with meaning implications and their connections with meaning implications threads in the conferences (English course)

Approximately half of the messages with meaning implications occurred within the same conference but a significant number of them could also be found either isolated or linking different conferences. Very few messages occurred in specific conferences having class statements or texts as their origin [Tab.9].

3.4.2.1 Hypotheses

The English course was very poor in hypotheses formulation. Few hypotheses were found and most of them when conditional meaning implications were part of a meaning implication thread but were not part of a VGroups thread [Tab.10].

The remaining hypotheses were identified among the messages and sub-messages that were part of conditional meaning implication threads that coincided with VGroups threads [Tab.10].

No hypotheses were found in messages and sub-messages when conditional meaning implications were not part of a meaning implication thread but were part of a VGroups thread; when conditional meaning implication threads coincided partially with VGroups threads; and when messages were not part of either meaning implication or VGroups threads [Tab.10].

HYPOTHESES	NUMBER	FREQUENCY	FREQUENCY IN THE COURSE
In messages in which there is connection with meaning implication threads only	11	84.6	6.1
In messages in which there is total coincidence between meaning implication and V-U VGroups threads	2	15.4	0.1
In messages in which there is: ● connection with V-U VGroups threads only ● partial coincidence between meaning implication and V-U VGroups threads ● no connection with both V-U VGroups and meaning implication threads	0	0	93,8
TOTAL	13	100	100

Table 10: Occurrence of hypotheses (English course)

3.5 Discussion

Assessing knowledge-building in traditional face-to-face education requires that we have access to the students' notes and their written papers. It is also necessary to interview both students and instructors. Assessing knowledge-building in online learning environments is somewhat different because it is an intentional learning process [Scardamalia and Bereiter 94] [Bereiter and Scardamalia 93]. Intentional learning processes are those in which learners take charge of their own knowledge-building process challenging the cultural idea of the primacy of instructors over students on the account that both have a lot to learn from each other. As users produce texts that are kept by the system, these objects of knowledge [Popper 94] [Bereiter 94] allow us to assess the process of knowledge-building directly. Although other ways of assessing knowledge-building cannot be dismissed, we argue that the resulting objects of knowledge provided by online learning environments are sufficient as long as all material produced is saved.

In the case of mixed-mode courses, a number of discussions, papers, and notes cannot be assessed. This fact interferes in the evaluation of knowledge-building processes. Even through interviews it is not possible to reconstruct the course. This applies to both courses in this study. But, despite this contingency, analysis of the data collected by identifying the flow of conditional meaning implications suggests that Virtual-U VGroups conferencing system supports knowledge-building by its design, although new features should be added to make it a friendlier learning environment.

In order to introduce the discussion, we should establish some similarities as well as differences between the courses studied. The first similarity between the courses is the occurrence of conditional sentences. The high percentage of conditional meaning implications encountered in both courses [Tab.1] [Tab.6] is a clear indication that reasoning depends on *"If...then"* operations, even when the subject of discussion is related to human and social sciences. It also suggests that knowledge-building processes in online learning environments are supported by those operations.

The higher percentage of conditional meaning implications encountered in the English course can be explained by its design. Students were asked to produce analytical and exploratory papers, usually long. Additionally, interaction among the students was low because it seems they were not fully aware of the possibilities of the VGroups threading feature.

In the Communication course, the exchange of ideas was encouraged, the use of the VGroups threading feature was generalized. Because of this a significant number of short messages with statements are responsible for the lower percentage as compared to the English course.

As both Communication and English are human sciences courses, they were likely to deal more with notions than with concepts. As concepts must be built upon very well-defined objects of knowledge within closed structures (models) to be considered as such, it is likely that their occurrence is higher in exact and biological sciences than in human and social sciences.

Indeed, building concepts from social and human sciences' notions requires mastery in difficult reasoning rules such as those of Aristotelian syllogistic. This fact explains another similarity: why the number of messages with necessary conditional reasoning found in both courses was so low. The occurrence of necessary messages was quite similar: 5.8% in the Communication course [Tab.2] and 4.7% in the English course [Tab.7].

Occurrence of messages with necessity and sufficiency, and necessity and absence of sufficiency was also similar and *always* related to actions such as "if I press icon *x* in the screen, then *y* will follow". The first was responsible for 2.7% in the Communication course [Tab.2] and 1.6% in the English course [Tab.7]. The second, 3.1% for both courses [Tab.2] [Tab.7]. There was a lack of advanced conceptual necessary reasoning in both courses.

The result is that the percentage of conditional meaning implications dealing with possibilities was high: 94.2% in the Communication course [Tab.2] and 95.3% in the English course [Tab.7]. This suggests that both courses had more exploratory discussions than arguments leading to strong conclusions.

In spite of these similarities, strong differences were found related to the use of the threading feature. The Communication course was highly interactive (the use of the threading feature possibilities was intense) with all users actively replying to messages produced by their peers, while the English course was very low in terms of use of that feature. Users concentrated more on their own text production, although contributions of their peers were taken into account.

Messages with meaning implication threads coinciding with VGroups threads totaled 39.2% in the Communication course [Tab.3] and 6.1% in the English course [Tab.8]; those with different origin and the same destination totaled 26.6% [Tab.3]

and 1.2% [Tab.8]; and those only connected with the meaning implication threads totaled 19.2% [Tab.3] and 63.8% [Tab.8] respectively.

It does not mean, however, that interaction did not occur as the appearance of the meaning implication threads indicate: 85% of all messages with conditional meaning implications were connected with meaning implication threads in the Communication course [Tab.3] and 71.1% in the English course [Tab.8]. The remaining 15% of the Communication course [Tab.3] was related to those messages only connected to VGroups threads and with no connection at all with either thread. In the English course, the remaining 28.9% [Tab.8] was related to those messages only connected to VGroups threads and with no connection at all with either thread.

We argue that knowledge-building occurred in both courses but in different ways. In the case of the Communication course, the building of knowledge, as meaning implication threads indicate, coincided totally or partially (85%) with the VGroups threading feature.

Although most users of the English course did not use the VGroups threading feature, the flow of meanings could be followed by meaning implication threads (71.1%) throughout the messages indicating knowledge-building. As message texts are objects of knowledge, the fact that even though most of the time the English course users posted their messages without replying to others, this does not necessarily mean that they were not interacting. Indeed, the analysis of the English course texts indicate that 77.2% of their messages were intended to reach all course participants while 22.8% were directed to specific users.

If compared with the Communication course, with 62.6% of the messages directed to all participants and the remaining 37.4% directed to specific users, we can conclude that independently of VGroups threading feature knowledge was built, although less collaboratively. Most of the messages of the Communication course were directed to all users, and text analysis indicates that students had difficulties in deciding to which message they had to respond, as the content of their messages would deal with ideas produced by more than one user. In the case of the English course, users did not have this problem as they were not using the threading feature.

An interesting finding is related to the relative inconsistency of Virtual-U VGroups threading feature as an optimal knowledge-building supportive structure. Although most of the messages with conditional meaning implication occurred within conferences (74.1% in the Communication course [Tab.4] and 51.1% in the English course [Tab.9]), a significant number of them were connected by meaning with other conferences (9.5% in the Communication course [Tab.4] and 18.9% in the English course [Tab.9]). Isolated messages correspond to 15.7% in the Communication course [Tab.4] and 27.8% in the English course [Tab.9], and other cases respond to 0.7% [Tab.4] and 2.2% respectively [Tab.9].

Making the connection of threads of different conferences possible would make Virtual-U VGroups a more consistent knowledge-building learning environment.

3.5.1 Hypothesis Formulation

The transcription and analysis of users' dialogues suggest that conditional reasoning scaffolds a collaborative problem-solving process through the generation of hypotheses when the flow of meaning implications coincides totally or partially with the Virtual-U VGroups threading feature.

Data comparing both the Communication course and the English course also suggest that although knowledge is built independently of this total or partial coincidence, a more consistent intentional learning only takes place with conscious use of Virtual-U VGroups threading feature.

Most of hypotheses built in the Communication course occurred when there was total or partial coincidence of the meaning implication thread and the Virtual-U VGroups thread [Tab.5]. In the English course almost all hypotheses were found where conditional meaning implications were part of a meaning implication thread. The use of Virtual-U VGroups threads is practically nonexistent. Very few hypotheses were formulated where there was total coincidence of the meaning implication thread and a Virtual-U VGroups thread [Tab.10].

Although data seems contradictory, text analysis of both courses suggests that hypothesis formulation is better supported by using the Virtual-U VGroups threading feature than not using it. Exploring problems, reasoning about necessity and possibility, posing questions to be answered, formulating hypotheses and problem solving are tasks that fit reasonably well into the Virtual-U VGroups threading feature.

The possibility of replying to previous messages and building threads supports those tasks because it organizes online discussions. When this feature is not used, discussions tend to be less collaborative as users explore more personal ideas, even when they are intended for others.

It is striking to note that data suggests that collaboration fosters hypothesis formulation. The number of hypotheses built by users was 730% higher in the Communication course than in the English course even considering that there were 159% more messages and sub-messages in the first. Occurrence of hypotheses was 4.6 times higher in the Communication course than in the English course.

3.6 Conclusions

The transcript analysis of the Communication and the English courses indicates that Virtual-U VGroups is a knowledge-building environment. We studied the process of knowledge-building by following the flow of conditional meaning implications in the courses' discourse.

Although the building of knowledge was promoted by conditional reasoning enhancing idea generation, linking, and structuring [Harasim 93] [Harasim 90], we argue that using the Virtual-U VGroups threading feature is more appropriate than not using it. The reason is that the high percentage of total or partial coincidence of meaning implication threads and Virtual-U VGroups threads in the Communication course indicates that it is possible to build structures to scaffold and to drive collaborative knowledge-building.

Courses that do not use the threading feature properly, as the English course, tend to be traditional, since collaboration is not fostered and participation tend to be more the dyadic student-instructor model than the circular student-instructor-student model.

Although we consider Virtual-U VGroups a knowledge-building environment from its design, it should be improved by taking into account Harasim's concerns that new models, assessment techniques, pedagogical methods and tools for online learning are needed to adapt education to computer technologies [Harasim 93] [Harasim 90] [Harasim, Hiltz, Teles and Turoff 94].

Our analysis indicates that knowledge-building cannot be constrained by conference "boxes" and that the natural course of the mind is to carry out meanings from one conference to another. The threading feature should also sort all messages of all conferences by date, author, and thread in a similar way to what it already does with single conferences.

Another necessary improvement to make the threading feature more mind-like is to restructure it in such a way that, instead of building knowledge through a tree, the user could do so in a neuronal-like way. The analysis of the conditional meaning implication threads indicates that in most cases they do not fully coincide with those of Virtual-U VGroups threads because users do not always respond to one single message. For example, users cannot at the same time respond to a message posted in a given conference thread and to another one that is connected to a different thread in the same conference. They are also not allowed to respond to a message of a different conference thread without abandoning the original conference, etc.

An ideal threading feature would be one that allows replies to more than one message, independent of their threads and conferences. A neuronal-like threading feature would be a better scaffold for knowledge-building. It is probable that in a feature like this more conditional meaning implication threads would coincide with Virtual-U VGroups threads.

3.6.1 Hypotheses

Data comparing both the Communication course and the English course suggests that Virtual-U VGroups threading feature scaffolds knowledge-building by supporting collaborative formulations of hypotheses. But improvements should be made. We argue that a pedagogical technique for formulating hypotheses together combined with a new feature for the identification of conditional reasoning could serve as a powerful tool for knowledge-building in asynchronous learning environments.

Applying such a technique to educational environments would promote the constitution of pedagogical methods and tools for online learning. These methods and tools should able to support new ways for learners to assess their objects of knowledge and evaluate them in terms of the new objects to be built, helping to adapt education to computer technologies [Harasim 93] [Harasim 90] [Harasim, Hiltz, Teles and Turoff 94] as learning is the construction of a set of objects of knowledge [Pea 94].

The pedagogical technique consists of the intentional identification by the user of conditional arguments in the messages of their counterparts, the understanding of their contextual meaning, the discussion of their necessity or possibility. When the

hypothesis is necessary and sufficient, it must be accepted, and discussion should continue on a new basis. But when it is necessary and not sufficient, or just possible, a problem-solving process is triggered and should be implemented by encouraging discussion on the basis of discussing hypotheses.

After this initial phase, the technique supposes the exploration of all possibilities by rebuilding a hypothesis already stated and/or formulating new hypotheses that would be more relevant from the user's viewpoint. This exercise of an in-depth conditional discussion triggers the construction of a chain of creative hypothetical arguments throughout the discourse, avoiding excess of statements and false problems that could, eventually, produce a less exploratory course.

In other words, the proposed pedagogical technique can be summarized as an intentional exercise of formulating hypotheses together by in-depth collaborative analysis of the arguments.

To support the pedagogical technique of formulating hypotheses together, a feature could be added such as a search-like tool that would automatically highlight questions and sentences where conditional reasoning might be under way. Questions would be identified by the sign "?". Possible conditional sentences would be identified by recognizing relevant words depending on language, such as "if", "then", "might", "would" (and others) for English, "peut-être", "si", "alors" and verbal conjugations that indicate conditional (and other words) for French, "mischien", "als", "zou", "dan" (and others) for Dutch and so forth. Then, tips would help users to navigate in the waters of conditional reasoning, guiding the learner to recognize necessity, sufficiency, and possibility.

We argue that a feature driving users to explore hypotheses together will lead them to in-depth discussion, divergent thinking, and organized conflict. Recent research suggests that students perform better when conflict is maximized and that when knowledge-building activity is also increased, conceptual change is more likely [Chan, Burtis and Bereiter 97].

Our findings suggest that when online group users build knowledge upon each other's hypotheses, a problem-solving process is triggered. This suggestion is consistent with previous research [Van Joolingen and De Jong 91]. Although Wouter van Joolingen and Ton de Jong did not work with an asynchronous learning environment such as Virtual-U VGroups, but with computer simulations in environments that made exploratory learning possible, their research suggests that formulating hypotheses supports a learning process.

A collaborative hypothesis formulation tool is consistent with Harasim's analysis that the formulation of arguments comes necessarily from interaction, and that it advances collaborative knowledge-building [Harasim 90]. It would encourage educators and learners to become actively engaged in a constructive, consistent, and in-depth collective effort to re-signify and restructure their object of study by producing relevant objects of knowledge [Popper 94] [Bereiter 94] leading them to notional and, perhaps, to conceptual change as well.

4 Conclusions

Asynchronous learning environments are computer-based conferencing systems customized for online education. In these environments, users do not need to work with their peers at the same time because posting can be done anytime and anywhere as long as there are available computers linked to the Internet and the World Wide Web.

Although educational roles people play have been institutionally defined by the historical and cultural constraints of the Western civilization, asynchronous learning environments challenge them by its unique technological nature. This is a surprising - and perhaps unexpected - contribution of technology to education.

This contribution of technology makes possible a revolutionary new pedagogic scenario in which collaboration is brought to the center of the educational interaction as asynchronous learning environments might, by the development of built-in pedagogical tools and techniques, replace the old-fashioned and power-based idea that education requires instructors "to teach" and students "to be taught". The idea of transmitting knowledge to students considered passive recipients of knowledge is cognitively inconsistent as education should be understood as an active dialectic process of symbolic interaction [Campos 96b] [Campos 95].

Learners engaged in an interactive knowledge-building process become subjects of their own learning destiny. Barriers between students and instructors collapse and their roles change as instructors become facilitators in a process of inquiry and problem-solving.

As asynchronous learning environments suppose intentional learning [Scardamalia and Bereiter 94] [Bereiter and Scardamalia 93], a creative knowledge-building process through collaborative learning is triggered. Studying ways to assess and evaluate these creative learning processes are central in modern research on computer-based education.

Consistent with the experts' demands of advancing educational research on computer technologies [Harasim 90] [Harasim, Hiltz, Teles and Turoff 94] we developed a transcript analysis technique to assess computer-based knowledge-building communication processes and evaluated their objective results in terms of learning. We also suggested the idea of a hypotheses generation pedagogical technique and built-in tool.

Both pedagogical technique, tool, and transcript analysis technique were conceptualized from the Piagetian model of knowledge and Popper's Three Worlds proposal. We considered transcripts produced by users in asynchronous learning environments as concrete results of knowledge-building communication processes.

Results suggest that our analysis was able to unveil, at least partially, those conditional reasoning processes of building and rebuilding of notions and concepts by learning minds collaborating in an asynchronous learning environment. Although results from the study of two mixed-mode online courses cannot be generalized, we argue that the results were an exploratory verification of the model we worked with.

New studies from other courses are necessary. They must include not only various disciplines from all fields of human knowledge, but also different kinds of courses including those completely online, and also courses developed in different countries to

assess cultural constraints in learning networks. Flows of meaning implication will possibly vary strongly according to the cultures in which the users are immersed.

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