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## State of the art of interaction analysis for Metacognitive Support & Diagnosis

Angelique Dimitrakopoulou, Argyroula Petrou, Alejandra Martinez, José Antonio Marcos, Vassilis Kollias, Patrick Jermann, Andreas Harrer, Yannis Dimitriadis, Lars Bollen

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Angelique Dimitrakopoulou, Argyroula Petrou, Alejandra Martinez, José Antonio Marcos, Vassilis Kollias, et al.. State of the art of interaction analysis for Metacognitive Support & Diagnosis. 2006. hal-00190146

**HAL Id: hal-00190146**

**<https://telearn.hal.science/hal-00190146>**

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## **D31.1.1 (Final)**

# **State of the art of interaction analysis for Metacognitive Support & Diagnosis**

Main author : Angelique Dimitrakopoulou (UAEGEAN)

Nature of the deliverable : Report

Dissemination level : Restricted

Planned delivery date : August 2005

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*Prepared for the European Commission, DG INFSO, under contract N°. IST 507838  
as a deliverable from WP31  
Submitted on 09-01-2006*

## Summary

The document concerns Computer Based Interaction Analysis that could support technology based learning activities' participants (e.g. students, teachers) or observers (e.g. teachers, researchers).

The underlying considerations and analyses focus on interactions that occur via technology based Learning Environments, designed for stand alone use or collaborative use.

Special emphasis is given on Interactions Analysis (IA) outputs that could support learning activities' participants in cognitive and metacognitive reflection and thus in selfregulatory operations.

The document aims to present the state of the art on Interaction Analysis (highlighting the current state as well as the new trends) in three complementary dimensions:

- (I) Design of IA tools and involved IA indicators
- (II) Applied Analysis methods
- (III) Research questions and related applied methodologies

## History

Filename	Status	Release	Changes	Uploaded
D31-01-01-F.pdf	Final	1	Corrections in english (mainly section I.3.2.) and some figures.	09/01/2006
D31-01-01-V1.pdf	Draft	1		10/10/2005

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**ABSTRACT**

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## Introduction: Content and status of the document

The document concerns Computer Based Interaction Analysis that could support technology based learning activities' participants (e.g. students, teachers) or observers (e.g. teachers, researchers). The underlying considerations and analyses focus on interactions that occur via technology based Learning Environments (**LE**), designed for stand alone use or collaborative use. Special emphasis is given on Interactions Analysis (**IA**) outputs that could support learning activities' participants in cognitive and metacognitive reflection and thus in selfregulatory operations. Additionally, the analysis pay a special attention in enriched learning environments and contexts designed or used under constructivists and social constructivists theoretical considerations, thus implying multidimensional and complex interactions.

Especially, the document presents the state of the art on the Interaction Analysis, pointing out in particular the current state and new trends, in three main dimensions:

- (I) Design of Interaction Analysis (IA) tools, and underlying IA indicators
- (II) Computer Based Interaction Analysis methods implemented to process in an automatic way the needed IA indicators
- (III) Research methods that were applied for the investigation of the effects of IA tools' use to the involved main learning activities' participants (students & teachers).

It is to be noted that even if the presented state of the art on Computer Based Interaction Analysis focuses on learning environments and contexts, it could be also useful for readers interesting in different technology based environments or contexts (e.g. context of work, context of professional or scientific virtual networks).

The document is produced by the work of the members of the Jointly Executed Integrated Research Project (JEIRP): "Interaction Analysis Supporting Students and Teachers' Selfregulation", supported and funded by the Kaleidoscope Network of Excellence [IST Technology Enhanced Learning:TEL/ 507838].

# I. State of the art of IA tools and IA indicators: Design Issues

*Angelique Dimitracopoulou*

## ***1.1. The sub-field of Computer Based Interaction Analysis supporting Selfregulation of Learning Activities Participants***

### **1.1.1. Field Definition**

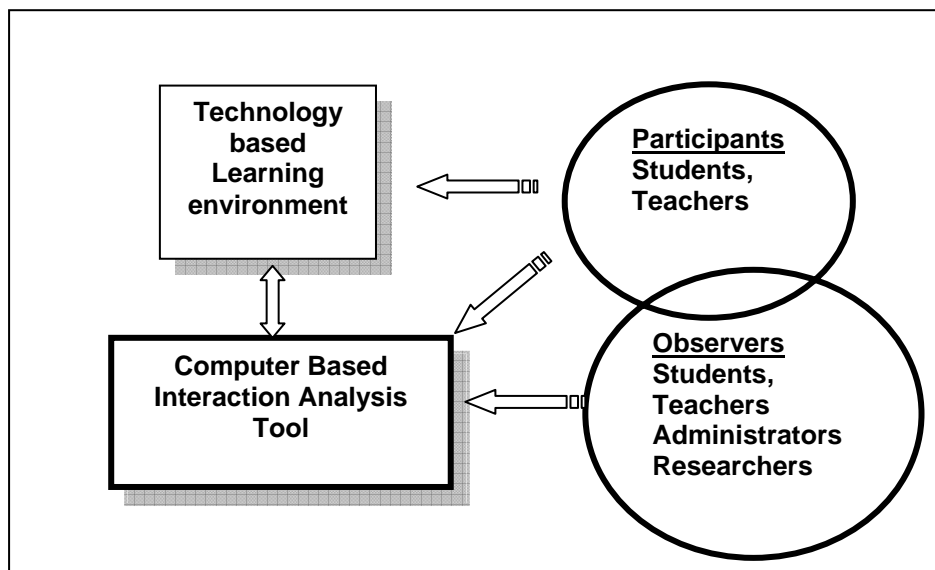
Computer Based Interaction Analysis that provides information directly to technology based learning activities' participants (usually students and/or teachers), in order to self assess their activity, is a new direction emerged during the last years mainly due to the very complex interactions that occur through the collaborative systems. The interaction analysis results that are shown to the participants of the learning activities' are displayed in an appropriate format [usually graphical, but also numerical or literal one], interpretable by the IA tool users. The corresponding information provide an "insight" on their own current or previous activity allowing the learning activities' participants to reflect on a cognitive or metacognitive level, and thus based on this reflection or co-reflection output to acquire the possibility to self-regulate their activities.

This approach can produce flexible interaction analysis tools, which support directly the technology based learning activities' participants (e.g. students, teachers) or even the observers (e.g. teachers, researchers) of these activities (see Figure 1).

In practical terms, the field proposes that the design of technology based learning environments must not be limited to the initial means of action and communication, but should be extended by providing means of analysis of the very complex interactions that occur, when the participants of the learning activities work in individual or collaborative mode, in formal or informal educational contexts. The need to support participants' awareness and metacognition is actually pushed by the intensive interest to use technology based learning environments and specially collaborative ones in every day educational practice, where there is a need to (self) evaluate in an operational way, both the learning processes and the quality of activity. In particular, it is to be taken into account that:

- ♦ Working in technology based LE is an activity more complex than in paper-pencil: it is difficult to be aware on «what we have done »

- ◆ Furthermore, the work in technology based social environments is an activity much more complex than the work in a stand alone environment
- ◆ In every case, it is very difficult for students to create an 'image' of their own activity, or this of other students/collaborators (as individuals, group or community).
- ◆ For teachers, it is very hard to manage activities in collaborative environments or in stand-alone systems, due to the very complex interactions that occur through and around technological environments, and this in different cognitive groups that are formed simultaneously.



**Figure 1. General profile of Users of Interaction Analysis Tools**

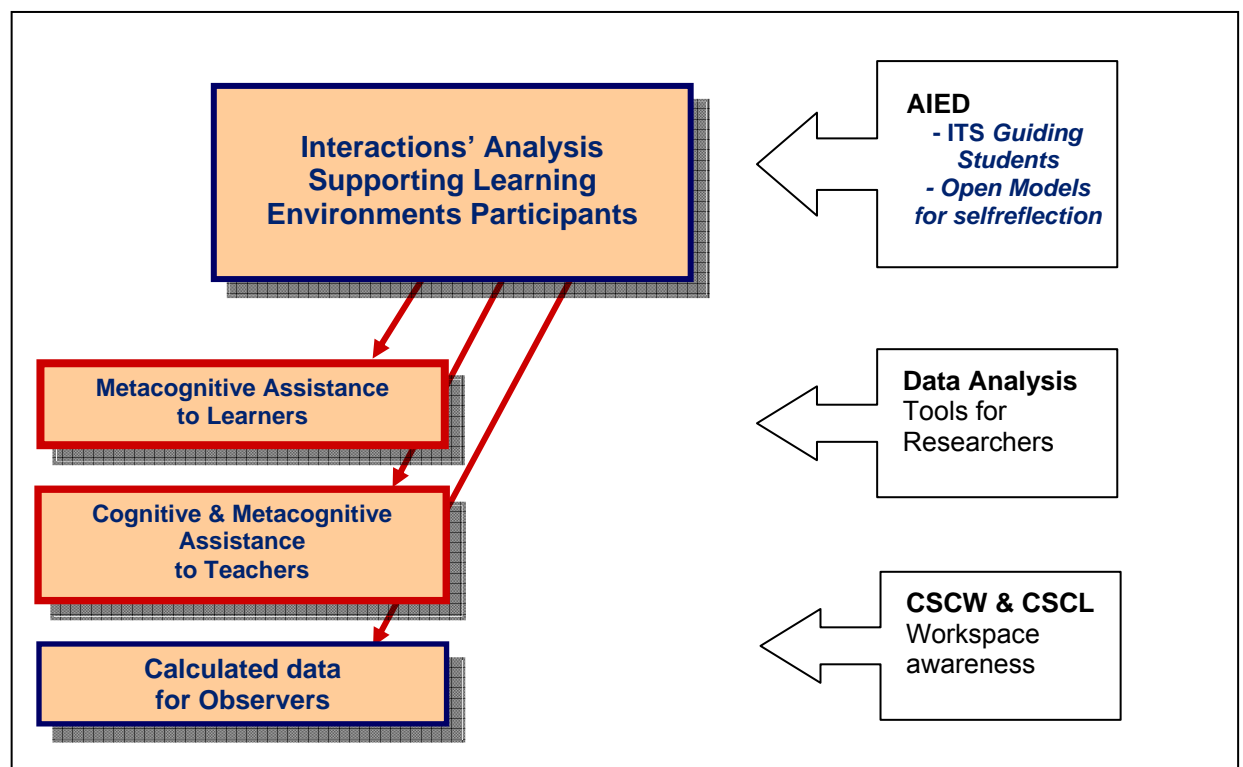
During the last few years designers and developers worked partially, to produce computer based IA tools, that constitute a distinct tool or a just a piece of software integrated to the learning environment.

One of the main actual challenges is to identify the common aspects and the differences among the current applied approaches, and motivate the researchers to produce more distinguished IA tools, as well as IA tools independent of the LE, something that could serves as an impulse in the researchers' community, as well as in the use of these tools from teachers and researchers.

### I.1.2. Fields-Sources, Related scientific sub-fields and applications

Computer Based Interaction Analysis is an area, a subfield, of the interdisciplinary scientific field of Information and Communication Technologies in Education. A number of other existing scientific subfields could be considered as the main fields-sources that contribute by their theoretical considerations, developed technological applications, and research results (see Figure 2):

- (a) Up the present the computer based Interaction Analysis related work was mainly done by systems that apply Artificial Intelligence inspired methods to compare Interaction Analysis results with an ideal case, and produce messages to guide students. The *AIED field* can be considered as a core field source and has contributed by specific directions of research, such as:
- i. -“*Learner Modelling for Reflection*”: (e.g. related workshops in AIED 1999, ITS2002, & AIED2003), working with open students’ models, thus models accessible to learners.
  - ii. -“*Metacognition and selfregulation in Learning with Metacognitive tools*”: (e.g. Azevedo et al., Workshop, in AIED, 2003)



**Figure 2: Field sources of the Interaction Analysis supporting Selfregulation field**

- (b) Technological applications supporting Social Sciences' Researchers are continuously designed and developed. There are applications that provide a computer support for the analysis of data collected by researchers, so as to allow them studying learners' interactions which take place through or around computer. Two general kinds of current applications exists: commercial tools, so called "behavioural observation software" such as the "Observer XT, Noldus" {www.noldus.com} (allowing data recording, qualitative and quantitative analysis) or prototypes from research laboratories, such as COLAT (Avouris et al. 2004)
- (c) Computer Supported Collaborative Work (CSCW) can be considered as another field-source. Researchers of this field have extensively worked during the last year on how to support a "workspace awareness", in social software, and they have already developed related frameworks, they have proposed solutions and techniques as well as they have presented research results. The aspects dealing with 'workspace awareness' concern only a part of the field of Interaction Analysis supporting Selfregulation.

## ***1.2. Framework of State of the Art Analysis***

The framework, allowing us to to define the state of the art analysis dimensions was developed iteratively over the last three years, and it is derived from a variety of resources:

- approaches and insights of other groups and researchers working on the field (and specially the pioneers: see for instance, Jermann et al. 2001, Soller et al. 2002).
- theories developed on learning, social constructivism, and specially those on group cognition
- previous work of LTEE laboratory on theoretical analysis, applications and study of how people perceive IA outputs
- the study and the discussions in the frame of ICALTS JEIRP related work (see deliverables D.26.1., D26. 2., & D.26.3).

### **1.2.1. Interaction Analysis Tool and Process**

Let us present briefly the main 'phases' involved in the computer based 'interaction analysis process' (Figure 3). Students interact with technology-based learning

environments. In different moments of the learning activity, they can interact with the environment individually, or by group (s), forming various cognitive systems. Additionally, a teacher may intervene or just supervise the whole collaborative activity.

In order to analyse participants' interactions:

⇒ Data are selected (data selection or data filtering), from the available data sources.

During interaction, two kinds of interaction data could be collected:

(a) the collaborative interaction *product* (its final form and eventually intermediary instances of this product, during the interaction)

(b) student(s) actions registered into the environment logfile, capturing the whole interaction *process*

⇒ The selected data are aggregated by different data processing methods. In some cases, preprocessing methods are needed (e.g. transformations of available databases in suitable shapes or intermediary calculations), so as to prepare the data in an appropriate way (e.g. needed for specific algorithms).

⇒ The application of 'data processing methods' produces usually one or more basic 'indicators' (usually low level indicators), as well as one or more composite, derived ones (high level indicators).

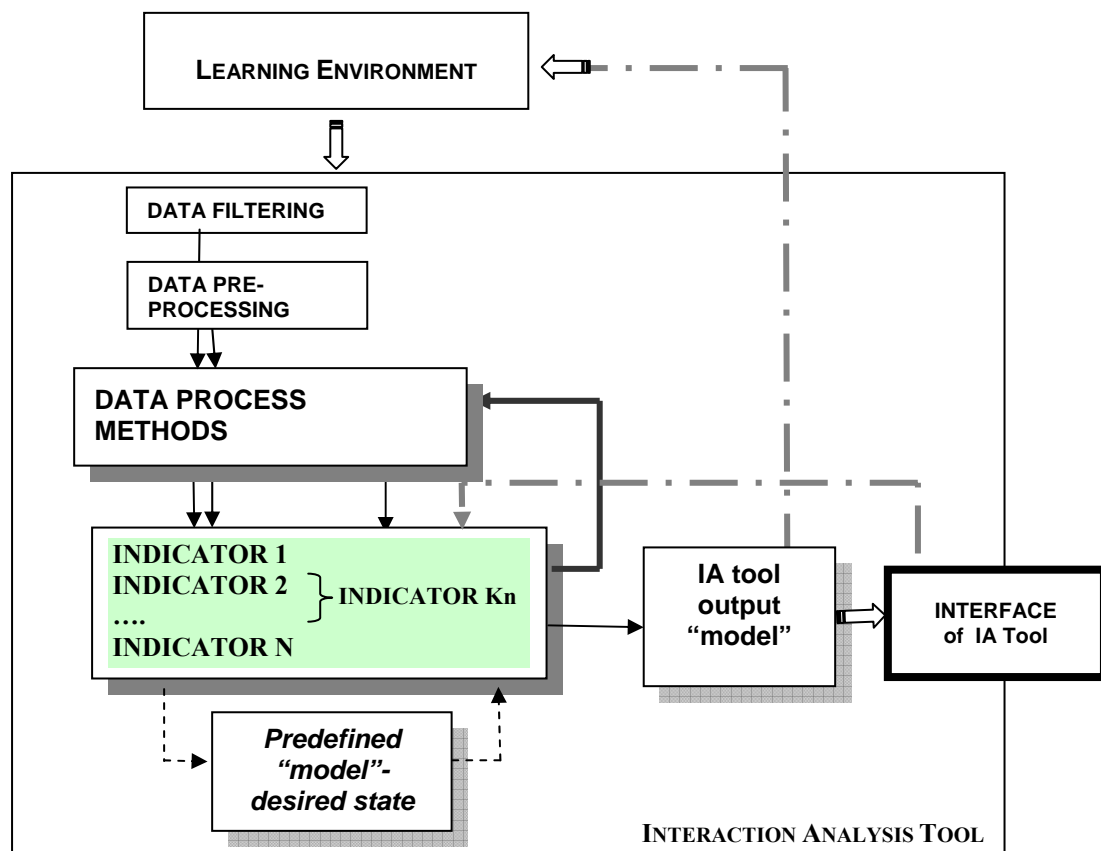


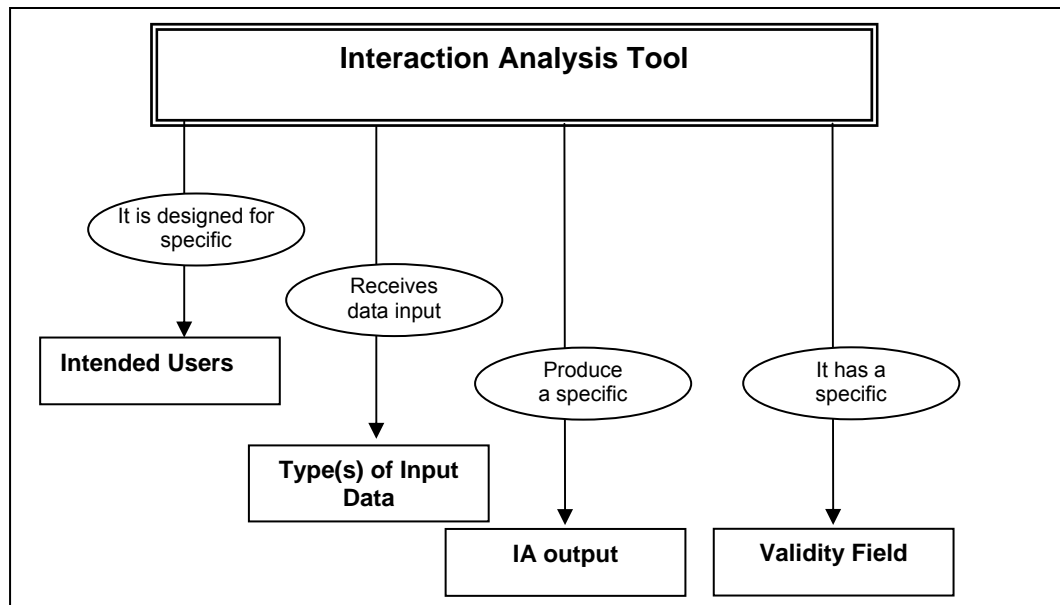
Figure 3. Generic Interaction Analysis Tool main processes stages

The IA indicators constitute variables that indicate 'something' related to the mode or the 'quality' of individual activity (e.g. variables that he/she change, order of significant actions, etc.), the mode or the quality of the collaboration (e.g. division of labour, participation rates, categories of specific contributions), the process or the quality of the collaborative product.

⇒ In the interface of the IA tool, the IA tool user can observe or even handle the output values of IA indicators. Concerning the presentation of the indicators' values to the users of interaction analysis:

- (a) The values of these indicators could be announced directly to the users via a specific *interface*. The presentation of the values usually takes an appropriate form: textual, numerical, or diagrammatic- visualized one.
  - (b) In some cases, the systems incorporate an assessment of the values of indicators (via a mechanism of 'calibration' according to specific norms), specified into the specific context of interaction (e.g. presenting a range of 'positive" and 'negative values").
  - (c) In other cases, systems interpret the meaning of the indicators values, comparing them with an internal suitable or even ideal model (desired interaction state) , and therefore proceed to the production of explicit messages advising students what to do. In the latter case, a guiding system is produced, (addressed usually to students).
- ⇒ When the IA tool is customizable by its users (e.g. teachers or adults students), it may allow them, via the IA tool Interface, to insert appropriate values for: (i) the indicators that wish to observe, (ii) the norms of some indicators, (iii) or even the desired model of reference if needed (e.g. in the previous case 'c').
- ⇒ It is to be noted that the output of an IA tool, can be visualised even in the Interface of the Learning environment, in case that it is useful during the interaction (e.g. indicators supporting 'workspace awareness' in social software).
- ⇒ Finally, the output of IA tool can constitute just information on some aspects of the interaction, or a more complete and coherent information, that takes the status of an 'interaction model'.

The whole 'system' that selects the needed data and aggregate them via data processing methods, producing indicators, and even developing appropriate forms of messages could constitute a distinct *interaction analysis tool*, or to be a piece of interaction analysis software/code, internal to the Learning environment.



**Figure 4: Interaction Analysis Tool core Features.**

We can consider that the very basic and core features of an IA tool is the following ones (see Figure 4): (a) the users that were considered by its designers, (b) the types of input data that can receive, (c) the kinds of IA indicators that calculate as output, and (d) the range of its validity.

## II. 2.2. Interaction Analysis Indicators framework

The Indicators play a central and crucial role on what an IA tool offers. For this purpose, and in order to proceed to the state of the art analysis, it is necessary to establish a detailed framework of analysis. It was initially elaborated in Dimitracopoulou et al. 2004, (D26.1, State of the Art on Interaction Analysis Indicators, ICALTS JEIRP).

### 2.2.1. IA Indicator Definition

Students interact with technology-based learning environments, in stand alone or in collaborative mode. Thus, students could interact individually with the environment or by group, forming various cognitive systems. During interaction, two types of interaction data could be collected:

- (i) the individual or the collaborative product (its final form and possibly intermediary instances of this product, during the interaction);
- (ii) students' actions registered into the learning environment' logfile.



Based on these interaction data, the application of 'data processing methods' could produce a number of "*Interaction Analysis Indicators*". These indicators constitute variables that describe 'something' related to:

- a. the mode or the process or the 'quality' of the considered 'cognitive system' learning activity (task related process or quality);
- b. the features or the quality of the interaction product;
- c. the mode, the process or the quality of the collaboration, when acting in the frame of a social context forming via the technology based learning environment.

Note that the ultimate goal of the interaction through a learning environment is to achieve:

- (a) a better activity process
- (b) a better activity product, or
- (c) a better collaboration,

that could result in better learning effects.

The users of IA indicators could be the student, the teacher (tutor or mentor), (*participants*) the administrator of a platform, the system, or the researcher (*observers*). In this document, we focus on how interaction analysis could support the participants of the learning process. We therefore concentrate on the students and the teacher.

In the ideal case, for each interaction session, a *number of complementary indicators* could be produced. These indicators could form an implicit "*model of the interaction*". This model is a surrogate 'construct', a conceptual understanding of the process that takes place or has taken place. This model would have three components:

- (a) A set of names of the *agents* that interact and the *means* that they use;
- (b) A set of descriptive indicators (variables) representing "aspects" of the interaction;
- (c) An interpretation, relating all the available descriptive indicators.

## 2.2.2. Interaction Analysis Indicator Attributes

### Indicator concept:

Each interaction analysis indicator is characterized by its main 'concept' (see Figure 5): the aspect of interaction that it represents (e.g. division of labor, collaboration intensity, participation rate, etc)

**Indicator Purpose:** The general purpose of the indicator could be described as being cognitive, social or even affective. It has to be further determined whether an indicator

can contribute to promoting awareness, assessment or evaluation. Note that the indicator purpose is directly related to the indicator concept. The possible exploitation of the indicator by the users (students or teachers) may be related to different aspects: A teacher could exploit the same information (e.g. a social indicator on awareness of actions within a group) for inferences on collaboration but also for managerial aspects (e.g. he or she may decide to change the members of a group).

**Indicator values:** the indicator takes values: **The form of the value** is a significant attribute. **The status of the value** refers to whether the interaction analysis output gives only a value, a calibrated value or an interpreted value.

**Validity field:** the validity field of each indicator should be explored and defined thoroughly, as well as the limits of this validity. In order to define the validity field, the kind of learning environment, the content of the activity, the learning participants profile and the intended users should all be considered.

**Participants of a technology based Learning Environment:** An indicator refers to the Participants of a technology based Learning Environment (LE). These participants could be a student, a group of students, a wider virtual community or a teacher.

**Interaction Analysis Indicator (IAI) Intended Users:** An indicator is used by Interaction Analysis Indicator (IAI) Users. These include the 'participants' of the learning activity (e.g. individual students, a group of students, a whole community of students, or a teacher), as well as eventual 'observers' of the activity (teacher, administrator, researcher). It should be noted that even if the indicator concept is the same, the values form or status may be different depending on the intended user.

It is to be clarified that the teacher may be a participant of the technology based interaction process (e.g. when he/she supervises a synchronous collaboration). In that case, specific indicators of the teacher's own role could be available for him/her.

**Time of use of IA Indicator :** There are two general cases of the time of use of an IA indicator output from the user of IA tool: (i) *On-line use of IA indicator*: this is usually the case where the participants of the learning activity can 'observe' and eventually exploit the information provided by the indicator value, during the interaction with the learning environment (e.g. indicators supporting 'workspace awareness' in social environments). (ii) *Post-hoc use*: The Post-hoc use of IA indicator, has the meaning that the IA tool user will have in its disposal the output of the indicator, "after the end" of an interaction session. When the IA tool user is an 'observer' of the learning process (e.g. teacher, researcher) can always receive the corresponding information afterwards the interaction. For the IA indicator user, which is participant of the learning process

(student, and/ or teacher), the post hoc use, often signifies that the indicator can not be calculated during the interaction (specially during a synchronous collaborative session), or the IA tool has limitations and cannot display this information.

**Dependencies:** The indicator may be dependent or independent from external variables (such as time, or content).

It may be useful to note, that there are two general categories of indicators:

- (a) time dependent indicators, describing aspects that evolve during the process of the interaction;
- (b) time independent indicators, usually describing global aspects of the final product or of the whole process, that are processed at the end of the interaction session.

**Learning Environment:** The interaction through different kinds of environments, as well as the different activity means provided to users, in most of the cases demands different indicators. It is useful to distinguish among at least three general categories of learning environments: (a) environments for individual use, (b) action based collaborative environments (usually demanding synchronous interaction) and (b) text production oriented collaborative environments (usually demanding asynchronous interaction).

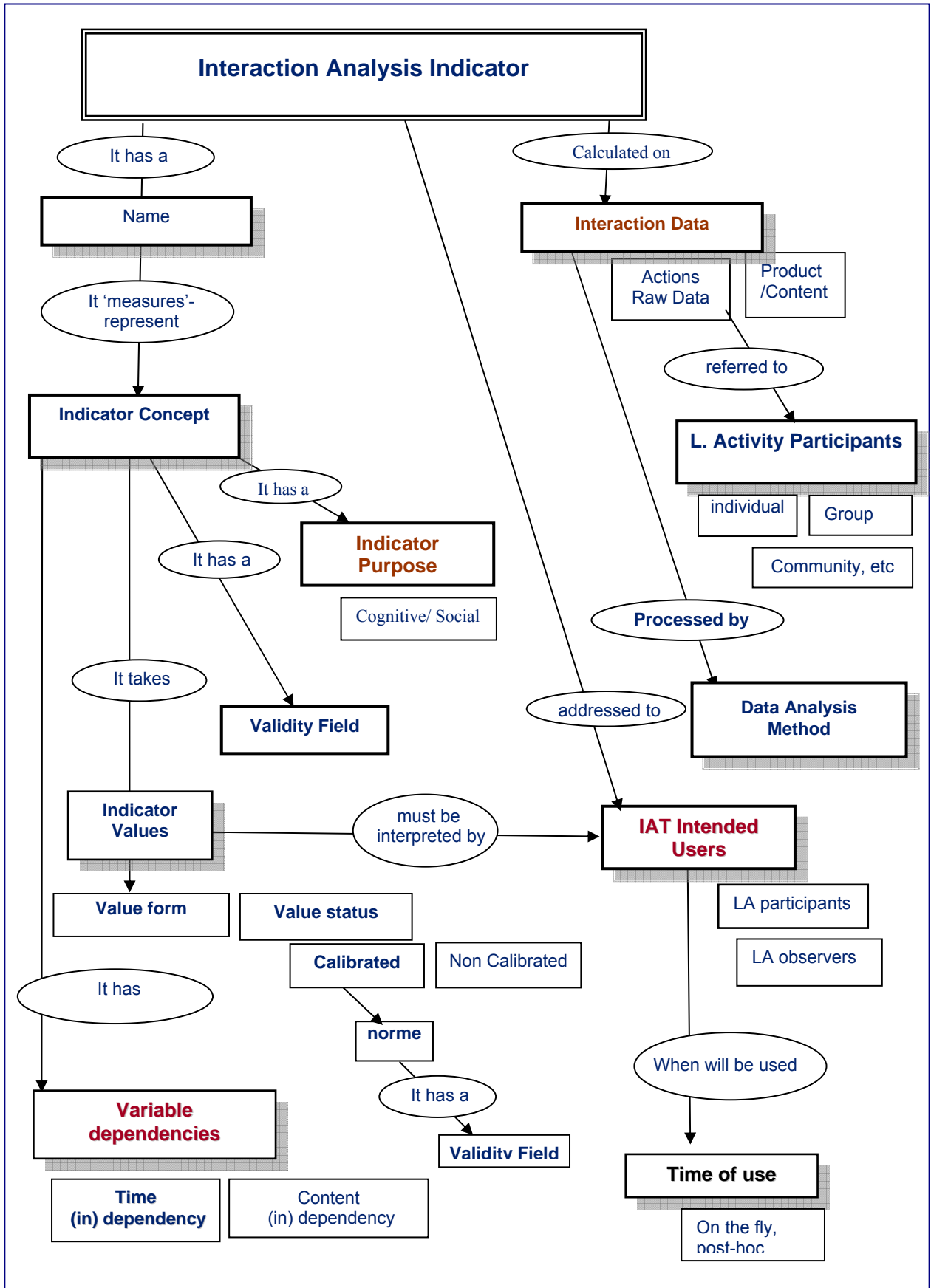


Figure 5: Interaction Analysis Indicators' Attributes

### 2.2.3. Significance, Interpretative value and interpretative schemas of indicators

We can make a distinction, among:

- (a) *High level indicators*: those that have an inherent interpretative value (e.g. psychological, pedagogical), and are usually inferred by complex process from the interaction data. Often these high level indicators are derived variables, calculated on the base of a number of lower level indicators.
- (b) *Low level indicators*, those that do not have an autonomous interpretative value and are usually inferred directly from the interaction data.

This distinction does not mean that high level indicators are better or more significant than the low level ones. The significance of these indicators cannot be estimated a priori. For instance, an indicator supporting “awareness” based on low level indicators concerning the participants’ actions could be more effective (in terms of how students take them into account in order to self regulate their activity) than the indicators assessing directly the quality of their final product, or of their applied strategy.

Another critical factor of the effectiveness of the produced indicators regarding student or teacher support, is the way of the presentation of the indicators’ values: literal information may be more or less effective than a direct guiding message on what students must do.

Concluding, the significance of the produced indicators has to be directly related to their effectiveness in supporting interaction participants, and can be estimated essentially only via experimental data, observing the effects of these indicators use by the IA users, themselves.

#### ➤ Interpretation of indicators (interpretative models or schemas):

It should be noted that when each of the indicators is interpreted by agents other than the participants: a teacher, a researcher or even the system, complementary information must also be taken into account, such as: other indicators, the learning activity product, the participants’ profile, the context of interaction, etc.

In fact, when we have to do with a number of indicators, it may need an interpretative schema that guides the meaning making from the defined and produced indicators, and allow to get a sense of aspects of the interaction.

We could distinguish two general kinds of these interpretative schemas:

- *Explicit interaction model*: Production of a complex system of indicators (usually a hierarchy of high and low level indicators), by the IA tool (*implemented model*).

- *Implicit interpretative schema of interaction*: Definition of an implicit but clear interpretative schema that guides the meaning making from the defined and produced indicators, and allow to get a sense of aspects of the interaction (*implicit model specified by the IA tool designer or the researcher*).

### ***1.3. State of the Art on IA tools and underlying Indicators***

#### **1.3.1. Analysis of existing IA tools**

The existing IA analysis tools will be analysed, according to their core design features, (see Figure 4).

The next sections present the current attributes of IA tools features, in some important aspects such as: (a) the *intended users* according to the designers (b) the types of input that they receive, (c) the type of Interaction “model” that they produce as output, as well as its power, and (d) their validity field. In fact, we try to answer the following basic questions, related to the current IA tools:

- (a) For which general profiles of users, are the existing IA tools designed?
- (b) Which kind of input data do they receive and process?
- (c) What is the status of interaction analysis output that they produce, and how powerful is it?
- (d) What is the validity field of each IA tool?

It is to be noted that the present analysis focuses only on the general level design features (choices). Other features of IA tools could be also analysed (e.g. interface, categories of produced indicators), however it is more fruitful to discuss on them, after the discussion on the micro-level of IA indicators. Furthermore, the technical issues of IA tools are not discussed in this section (analysis methods, platforms of development, interoperability, etc.)

##### **1.3.1.1. Intended Users’ profiles of IA tools**

The Main general profiles of IA tool users’ profiles, in educational settings, are typically the following (see Table 1):

- (a) Students, (b) Teachers & other teaching staff (participants or observers), (c) Researchers, and (d) the Learning Environment itself.

The last case, is the one where the output of IA tool is taken into account by the system (the learning environment itself), in order to send guiding messages to the students. In this case, the exact output of the IA tool (which is usually a piece of software internal to the Learning environment) is often hidden from the users.

However, there are systems that we could say that constitute mixed approaches, and they are addressed to more than one user profiles, such as :

( c) for both students and teachers, or for (d) teachers and researchers.

When the IA tool designer considers two general users' profiles, it may signifies two distinguished cases:

(i) there are two parts of the IA tool output addressed to each one of the users' profiles,  
 (ii) the same outputs could be read by both of them. For instance, it is obvious, that each IA output addressed to students can be also used by teachers (even if they have not all the needed information), or every IA output addressed to teachers can be read/used by researchers, even if the latter would need supplementary information so as to make sense of the interaction.

**Table 1: Main Users' Profiles of IA tools**

	<b>Users Profiles</b>	<b>IA Tools Examples</b>	<b>Authors</b>
(a)	Students	i-bee	Mochizuki et al. 2005
(b)	Teachers {mentors, managers, etc) - Participants  - Observers	COLEMON tool  * * "Activity Analysis in project manager"	Fessakis et al. 2004  Despres, 2002 Gerosa et al., 2005 Jermann 2004
(c)	Researchers	"Observer XT" "Interaction Level' Tool	Noldus Schummer, et. All. 2005
(d)	System (LE)	IA tool in COMET	Soller 2002
	<i>Mixed approaches</i>		
(e)	Students and teachers	"Activity Analysis" Tool {ModellingSpace Separate Component} DIAS IA tool	Dimitracopoulou, et al. 2002, Avouris et al. 2003 Bratitsis 2005,
(f)	Teachers and researchers	-	-
(g)	Teachers and System	« Teacher Asssistant »	Chen, 2004

\* The IA tool is not named

The difference between the intended users profiles deal (in a great degree) with the following:

- the ability of the user to decode the visualizations produced by the indicators variation (e.g. the reader can compare the images of the Figures 6 & 7)
- the ability of the user to understand the meaning of an indicator



- the ability of the use to assess the values of an indicator (in case that the indicator value is not calibrated).

For instance, we cannot expect that a teacher can decipher easily series of outputs like the interaction level diagram (IA (t)) (Schummer et al, 2005) presented in Figure x.



Figure 6. Example of IA tool output addressed to Students (i-tree, Nakahara et al. 2005)

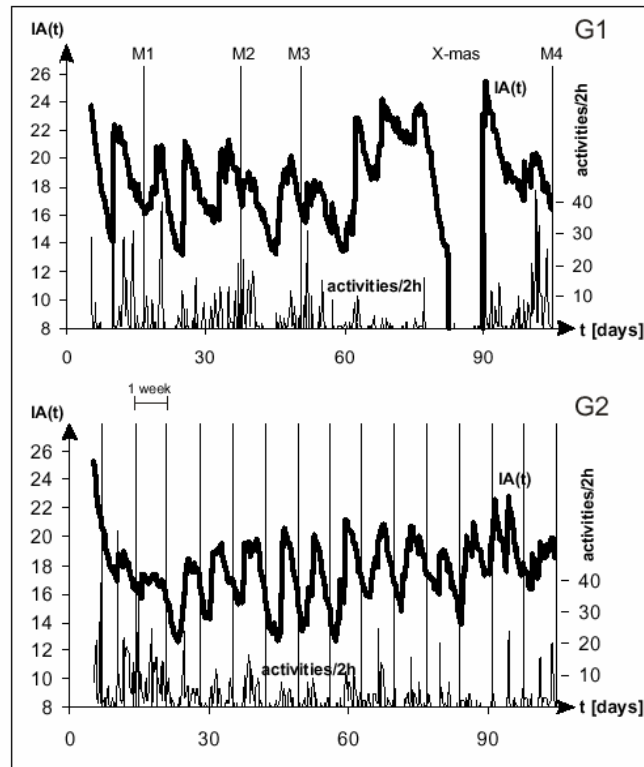


Figure 7. Example of IA tool output addressed to Researchers & Teachers (Schummer et al. 2005)

#### Current situation on existing IA tools for specific users:

The current situation, related to the existence or not of available IA tools, differs according to the domain/ the kind of learning environment that is supported by IA tools. For instance, with regard to the Forum like systems addressed to a wide public, there is a progress on the development of IA tools for Forum administrators, forum 'mentors', and teachers, while there are less IA tools or partial indicators for students. In fact, there are some tools that provide indicators that really analyse the interactions so as to allow teachers/mentors to supervise and assess the whole process, while concerning the learners, other tools provide basic information in the level of workspace awareness (how many new posts, who is on-line, etc).

In the contrary, with regard to the collaborative learning environments for synchronous collaboration: most of the IA tools available are addressed directly to students themselves, while IA tools for teachers are missing. This lack, accentuates the

difficulties to integrate exploratory technology based learning environments and especially collaborative ones in every day school practices, where the load of supervision and assessment by the teacher is extremely high.

Globally, there are really very few IA tools that are addressed to all the participants of a learning activity (teachers, mentors, students, etc), in an intended and well designed, distinct way, in function of their abilities and needs. In this direction, it is expected that there will be a progress during the next few years.

New trends: From the distinction of users' general profiles to the recognition and dynamic distinction of users' roles:

Besides the need of the development of IA tools that recognize the different users' profiles and fulfill their needs, new trends appeared recently, exploring further the possibility to recognize and dynamically distinguish different users' roles (Marcos et al. 2004).

In fact, a more complete and dynamic vision is needed, in order to:

- (a) cover the needs as well as the cognitive possibilities of the various cognitive systems that are formed during complex interactions (e.g. collaborative ones), as well as
- (b) explore more flexible and eventually powerful possibilities related to the functions and roles of participants' support.

The workshop organized by the participants of ICLTS JEIRP (see, Dimitracopoulou et al. 2004, as well as the whole workshop material in [www.rhodes.aegean.gr/LTEE/kaleidoscope-icalts](http://www.rhodes.aegean.gr/LTEE/kaleidoscope-icalts)) entitled: "*Interaction Analysis Supporting Participants during Technology-Based Collaborative Activities: Tailoring Collaboration Analysis Indicators for Different Types of Users*", (Lausanne, October 2004, CSCL SIG Symposium), has contributed in two complementary dimensions:

(A) Identification of different types and profiles of users, in different contexts/conditions of learning environments' use. Authors work contributes by:

- (a) Analysing and categorizing the different roles identified in the literature concerning students and teachers [Martinez, et al. 2004]. In particular, the authors have extensively worked on the identification of various roles that are pre-established or emergent during learning activities. (See also Marcos, et al. 2005).
- (b) Identifying and representing various possible social structures, in order to apply appropriate policies [Barros, et al 2004.]

- (c) Pointing out the potential of focusing the analysis, in a combination of cognitive systems [Kollias, et al 2004.]
- (d) Presenting a rough taxonomy of interaction analysis users' types, concerning the learning environments applied in primary and secondary education, that presents different cognitive abilities or even motivation to use interaction analysis outputs [Fessakis et al. 2004]

(B) Specific proposals on how to 'adapt' the interaction analysis output to these profiles:

Authors work contributes by:

- (e) Discussing on the cognitive possibilities of each cognitive system, through an analysis of metacognitive needs and self regulation possibilities, and proposing the incorporation of the possibility to shift the control progressively from 'external regulation' (guidance) to 'internal one' (self-regulation [Jermann 2004])
- (f) Proposing customizable agents, in the frame of a vision of 'social empowerment' [Morch et al. 2004]
- (g) Proposing customizable visualizations of indicators [Harrer et al. 2004], and more generally, optional interaction analysis tools [Fessakis et al. 2004]

### **I.3.1.2. IA tools Input Categories**

We could initially consider, that the data that serves as input in the IA tool are related to the kinds of learning environments that the IA tool may support and analyse their interactions. For instance, a Learning environment for stand alone use that is action oriented (simulation based, or modeling based systems), need to give as input to an IA tool all the logfiles as well as the content of the interaction products.

However the IA tool, even if it accepts all the data may process an analysis that is only oriented to the actions during the activity and not the product itself. Similarly, for collaborative learning environments, that are text production oriented (e.g. Forums, FLE3 etc), an IA tool may receive all the data (students actions, posts categories, posts content), however it may be able to take into account only the actions, during the IA process.

That means that we have to clearly distinguish the category of data that an IA tool receives as inputs, as well as the processed applied on these data.

<b>Input Categories</b> <b>LE categories</b>	<b>IA Input : Actions</b> => Activity Oriented Analysis	<b>IA Input: Product</b> =>Product/Content oriented analysis	<b>Authors</b>
<b>Collaborative LE:</b>			
Text production: Synchronous	SAMSA & SNA	--	
Asynchronous	+i-bee, +e-tree +FLE2, +Degree	+ i-bee, - - +Degree	Mochizuki et al. 2005 Nakahara et al. 2005 Morch et al. 2002 Barros 2002
Action oriented:	+IA tool, for "action-dialogue balance" +CoolModes IA tool +COLER IA component +CAF	- +CoolModes IA tool +COLER IA component -	Jermann, 2004 Gabner et al 2003 Conzalez et al. 2001 Fessakis 2004
Mixed			
<b>Stand alone LE :</b>			
Text production:			
Action oriented:	+Activity Analysis, MS	+	Dimitracopoulou et al., 2002
Mixed			

Table 2: IA tool data input categories

Current state: Most of the systems take into account the actions from the raw data, and not the content of the interaction product. Even if they receive as input the product, often they take it into account it as a number of actions (e.g. the number of words of a message posted in forum, or a chat message).

Even if different categories of learning environments exist, the categories of input data are not so different. Obviously, different kinds of contents need different methods of analysis, but, a system that incorporates a variety of analysis methods could handle these issues. What we have to think on, it is that the variety of Inputs categories are not so wide as it seems to be.

New trends: To create tools that:

- receive as data both actions and content of interaction (interaction product, collaborative product).

- unify the data categories: so as to progressively allow that different types of data (in various forms), to be received by a wider variety of IA tools.

### 1.3.1.3. Interaction Analysis Output Model and its Powerfulness

What's the meaning and the general purpose of IA tools supporting the learning environment users, so as to self-regulate their activity? It is to help users to create a global but also detailed image of the interaction, of the quality of their product, of the process etc. This global more or less complete image is a kind of model of the interaction.

How able are the actual IA tools to provide such a model ?

**Table 3: IA output and levels of model powerfulness**

	<b>Levels of Power</b>	<b>IA Tool Output Model</b>	<b>Authors</b>
(i)	Low	Restricted number of disconnected indicators	Most of the existing IA tools
(ii)	Intermediary	Coherent but partial set of indicators	Degree IA tool, Barros et al. 2002 I-bee, Mochizuki et al. 2005
(iii)	High	"Complementary & coherent Indicators sets: forming a model	---

#### Current situation:

We can distinguish three levels of IA tools output powerfulness (see Table 3):

- Low level:* Tools provide a restricted number of indicators: usually, it concerns tools that provide a few indicators, mostly disconnected, provided by IA tools internal to the LE.
- Intermediary Level:* Tools provide a coherent but partial "set of indicators": A characteristic example of this category is the output IA model, produced by the Degree learning environment (Barros, 2002), which provides a coherent set of indicators related to the collaboration quality (see Figure 8).
- High Level:* Tools provide "models of interaction": The higher level of IA model output corresponds to models that contain all the aspects of interaction (e.g. all implicated cognitive and social aspects). This kind of IA tools do not exist yet.

In fact, this categorization represent the actual state of an emergent field in progress, where still very few system provide a global image of the interaction.

Global Analysis for experience ENTORNO2					
ATTRIBUTES	- VALUES +				INFERED FROM
Argumentation	absent	low	suitable	Rich	DephTree Interactivity Initiative Work
Colaboration	awfull	normal	good	veryGood	Argumentation Cooperation Coordination
Conformity	low	intermediate	high		
Cooperation	null	low	intermediate	good	Argumentation Conformity Creativity
CoordinationMessages	little	enough	much		
Coordination	low	suitable	good	high	Argumentation CoordinationMessages Initiative
Creativity	low	intermediate	high		
DephTree	low	average	high		
Elaboration	low	suitable	high		
Initiative	low	intermediate	high		
Interactivity	low	middle	much		
MContributinsNumber	little	appropriate	much		
MContributinsSize	short	average	long	VeryLong	
Work	little	suitable	high		MContributinsNumber MContributinsSize Elaboration

Figure 8a. IA Indicators set of the Degree learning environment, related to collaboration quality

It is to be noted that the powerfulness of IA output is also related to the interpretative value of IA indicators. Most of the current IA tools, produce mainly *low level indicators* (basic variables, with low interpretative value). There are a few systems that reach to produce high level indicators, often consisting of a combination of a number of lower level indicators (see for example, the definition of the Indicator: collaboration quality, taken by Barros, 2002, Figure 8b).

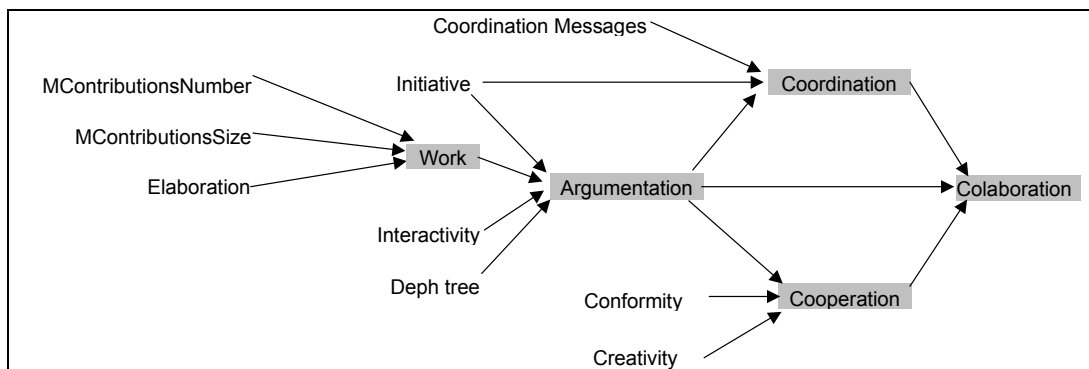


Figure 8b. Relationship among DEGREE indicators for obtaining the Collaboration Indicator

**New trends:** It is expected that the focused/detailed but also complementary work of an increasing number of researchers (contributing actually on the filed), as well as more complete works of specific research groups, will contribute so as to produce gradually more powerful models: That means IA outputs, that could offer:

- (a) a complete image on various aspects (quality of the interaction product, interaction process qualification, collaboration quality etc.); more complete indicators sets, that could constitute a model of the interaction or the learning process,
- (b) indicators sets that are appropriate for the different cognitive systems that are formed,
- (c) Indicators adaptable so as to be appropriate in the various learning activities and settings
- (a) Indicators sets that form partial but complete aspects of the interaction vising specific aspects (e.g. collaboration quality)

#### **I.3.1.4. IA Tools Validity field**

Each piece of software has a “field” (a variety of cases) in which can be applied that defines its validity field. An IA analysis tool can have a more or less restricted validity field, according a number of factors:

- (a) *Dependency of a specific Learning Environment (LE):* A IA tool can be:
  - *Learning Environment dependent:* it is the case where the IA tool constitute a piece of software, a component of a LE.
  - *Learning Environment independent:* it is the case, where the IA tool is independent of a specific LE, and can be directly or indirectly connected to a restraint or large category of LEs.
- (b) *Dependency of a specific domain of Activity:* An IA tool that is LE independent can be furthermore:
  - *Domain dependent:* e.g. dependent of a specific learning activity category (e.g. specific types of models, exercises, specific types of texts produced in a specific area, e.g. mechanics)
  - *Domain independent:* when it is not restraint from a specific domain (e.g. IA tools that work on forums in general)

**Table 4: Validity Field of IA tools: Factors affecting restriction of their validity field**

IA tool dependencies	Examples of IA Tools	Authors
Dependent of LE	IA tool in Degree	Barros, 2002
Independent of LE	CAF, DIAS	Fessakis et al, 2004, Bratitsis et al. 2005
Content dependent	IA tool in COLER *	Consalez, 2001 Despres, 2002
Content independency	IA tool in Degree i-bee e-tree 'Teacher Assistant'	Barros, 2002 Mochizuki et al. 2005 Nacahara,et al. 2005 Chen, 2004

**Actual state:** Most of the current IA tools are dependent of their LE. This situation restrains an expanded use of IA tools that could fulfill the actual needs.

**New trends:** The actual effort is to produce IA tools that have a large Validity Field, thus more independent tools.

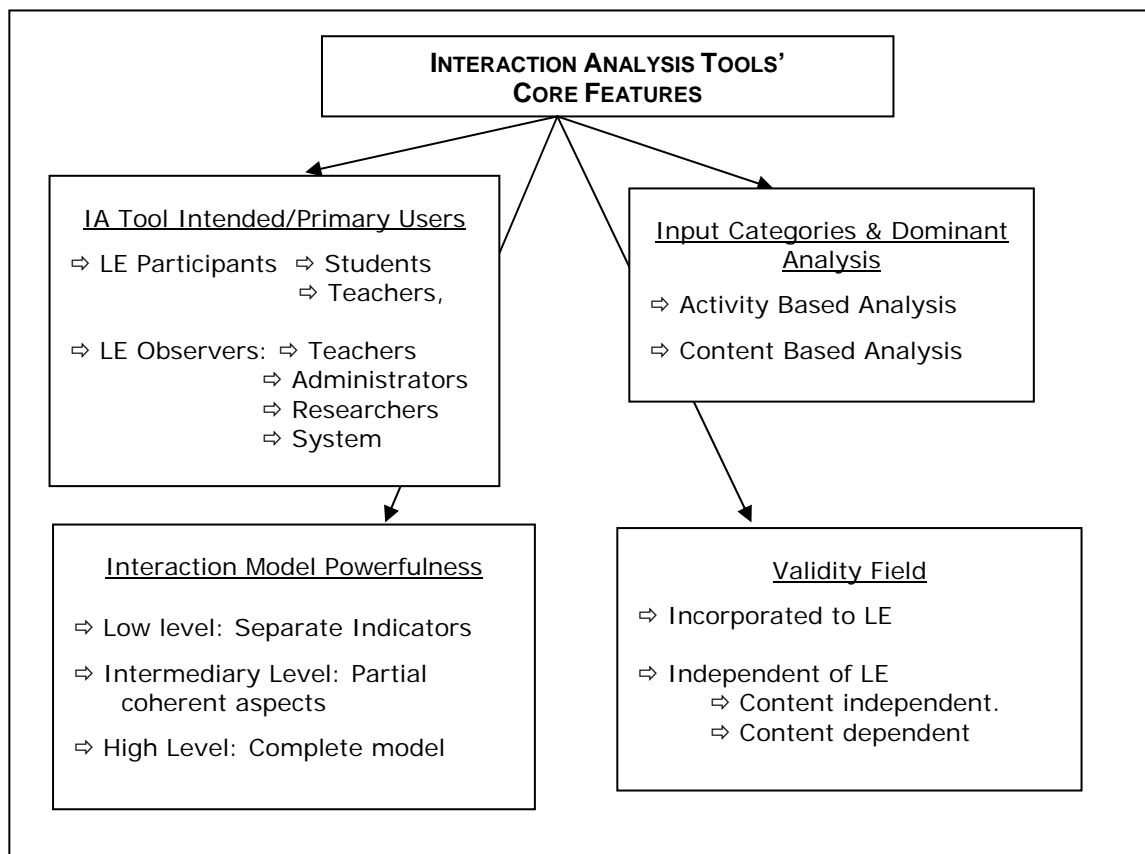
- ⇒ (i) *From LE dependent to LE independent IA tools:* this trade off could be resolved, specially when the output of IA tool does not support users in a direct evaluation level (e.g. when they don't provide to users guidance or evaluation ratings)
- ⇒ (ii) *From content dependent to content independent:* More work is actually needed by designers to explore the common aspects of indicators needed to analyse the data of different learning environments. Furthermore, it is needed to create customizable IA tools allowing to experienced users (e.g. teachers) to choose, or adjust the indicators.

One of the objectives of "IA JEIRP" is to make an effort and contribute in the direction to produce more independent IA tools. This effort could contribute in a significant way to the production of IA tools, and specially on the use of these tools, in each technology based learning activity. Specially, the work of the task 2, (incorporated in Deliverable 2) is a step on this effort (mostly related to the production of LE independent IA tools).



### I.3.1.5. Conclusions

We have examined the current state of the IA tools, as well as the new trends that appear, under the request of theoretical considerations and/or identified needs. We have focused on a few but core features of these IA tools, such as: (a) their users' general profiles, (b) the categories of data inputs, (c) their output categories and their powerfulness levels, (c) their validity field and their dependencies.



**Figure: Core features of IA tools and their current attributes**

The primary *IA tools User's profiles* are distinguished in: (a) participants of the Learning Activity and (b) Observers. The current IA tools are not designed so as to identify and fulfill the needs of more than one User profile. All of them are mostly addressed either to the students, or the teaching staff, or the researchers. However, there is an urgent need for distinction of the different potential users, and for the fulfillment of their needs.

Moreover, a promising direction is not only to distinguish these profiles, but also to dynamically recognize (a) the various roles that the participants of a Learning

Environment may play during the interaction, (b) the cognitive systems that they formed during the interaction and create their own needs.

The main *IA tools' input categories* are the raw data (actions registered in logfiles) and the interaction products during a session. Initially, we thought that the IA tools are strictly related to the kind of LEs, or even to the specific LEs. Finally, even if different categories of learning environments exist, the categories of input data are not so different. Most of the systems take into account the actions from the raw data, and not the content of the interaction product. Even if they receive as input the product, often they take it into account it as a number of actions (e.g. the number of words of a message posted in forum, or a chat message).

Obviously, different kinds of contents need different methods of analysis, but a system that incorporates a variety of analysis methods could handle these issues. What we have to think on, it is that the variety of Inputs categories is not as wide as it seems to be. It is needed to work more to find common aspects and differences, so as to progressively allow that different types of data (in various forms), could be inserted in a wider variety of IA tools.

Concerning the quality of *the IA tools outputs* and their *powerfulness to create and represent* a model of the interaction that has taken place, we have to admit that currently is not sufficient. Actually, there are not IA tools able to give as output a model that represents all the aspects of interaction (e.g. all implicated cognitive and social aspects). Most of the current tools provide a restricted number of indicators, mostly disconnected, while there is only a few IA tools that corresponds in an *intermediary level of powerfulness*, producing coherent but still partial “set of indicators”:

In contrary, it should be needed to reach to develop IA tools that produce a complete image on various aspects of the interaction (cognitive, social, taking into account the product and processes), offering more complementary indicators sets that could construct a model of the interaction and the emergent cognitive systems.

With regard to the validity field of the IA tools, actually most of the existing IA tools are dependent of their LE. This situation restraints seriously an expanded use of IA tools, that could fulfill the actual educational needs. The actual effort is to produce IA tools that have a large Validity Field, thus producing independent tools. That means (a) *LE independent IA tools*: something that it is not so hard to reach (specially when the output of IA tool does not support users in a direct evaluation level (e.g. when they don't

provide to users guidance or evaluation ratings)), and (b) *Content independent IA tools*: More work is actually needed by designers to explore the common aspects of indicators needed to analyse the data of different domain areas.

In every case, *customizable and optional IA tools*, is a promising direction that could help to face the problems of restricted validity field of IA tools, the one of low powerfulness of IA output, as well as this of not fulfillment of various users' profiles. In particular, it is needed to create customizable IA tools allowing to experienced users (e.g. teachers) to: (a) choose the most appropriate indicators list, in a specific interaction context, (b) adjust them defining their norms, or even their visualization modes.

### I.3.2. Analysis of IA Indicators calculated by IA tools

The presentation of the state of the art on IA tools supporting LE participants' self-regulation, can not be essential, without a detailed analysis of the IA Indicators that are produced from these tools.

The general features of IA indicators were presented in previous section (see, section I.2.). The scope of this section is to analyse in a detailed way the attributes of IA indicators, that are critical for the quality of an IA tool output. In particular, they are extremely important the following attributes: (a) *purpose* of IA indicator, that has to do with its nature (cognitive, social, etc), (b) *the output* of the calculated indicator, regarding to which cognitive system is referred by (the individual, the whole group, etc) when there is a social interaction, (c) the existing *forms of IA Indicator values*, (d) the *status of the Indicators' values* (calibrated, non calibrated, etc) that influences the levels of assistance providing by an IA indicator. Additionally, a critical aspect, which is not necessarily an inherent attribute of an Indicator, depending often by the IA tool designers' choices, concerns the representation and *visualization of the indicators' variations* in function to other dependent or independent variables. This is critical because it corresponds in fact on what it is presenting to the IA tool user.

Concretely, in this section we will explore the answers in some critical questions, such as the following:

- ◆ Which is the purpose of interaction analysis provided by IA indicators
- ◆ Which are the points of view of IA indicators on formed cognitive systems? Who is referred by the specific IA output?
- ◆ Which are the main forms of IA indicator value?
- ◆ Which are the levels of assistance provided to the IA tool users by each IA indicator (determined by the status of the indicator value)?
- ◆ How the IA indicators' variations and co-variations are represented? What kinds of visualizations are produced? How is it considered the dependence of IA indicator by the time-variable? What is produced by the combinations of indicators?

The analysis of the state of the art on these significant attributes will guide us to determine the current state as well as the new trends in IA indicators, pointing out, in concrete terms, the actual scientific achievements, as well as the prospects of the corresponding field.

### I.3.2.1. Purpose of IA indicator

The Purpose of indicator is to show up aspects of interaction (between student-LE, or among student-students-LE), that deal with three main general dimensions:

- (a) *The Cognitive dimension*: indicating something on the cognitive operations related to the learning activity content, or more generally, the learning activity (task) actions.
- (b) *The Social dimension*: related to the collaborative/cooperative or just communicative activities in a group or a community of participants, and
- (c) *The Affective dimension*: related to affective situation of the learning activity participants.

**(A) Cognitive Purpose's IA Indicators:** Cognitive indicators concern the actions of the individuals in the learning environment, related to the task of the learning activity. These indicators may refer to:

- the process of the activity or
- the product of the activity: (features of the interaction product: e.g. elements of the solution, discussion topic coherence among all the members in a discussion forum, etc).

Concerning the level of interpretation of each indicator regarding the cognitive operations of participants: (a) There are cognitive indicators that try to capture the intentions of learners while they perform these actions (according to de Jong, & Huslhof, 2005). These indicators have a high interpretative value. (b) Additionally, there are cognitive purpose indicators, with a lower interpretative value that just provide partial aspects of the cognitive activity, without making inferences on participants' intentions and cognitive operations.

**Examples of cognitive purpose's Indicators:**

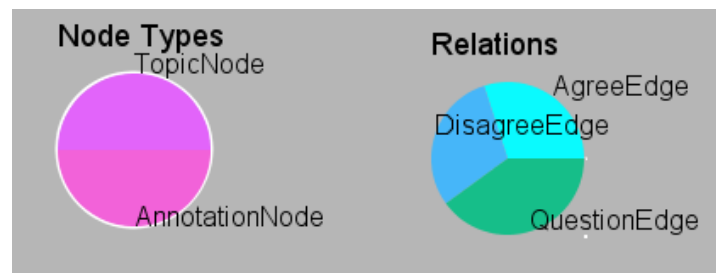
There are cognitive purposes indicators that refer to the product of the activity, such as:

- "the key topic of each member": what is the central theme of the forum messages of each member (e.g. keyword) (i-bee, Michocuzi et al, 2005), or "number of existing posts per message category or per topic", (FLE2, Morch, 2002, Chen 2004)
- the "nature of 'entities'" that constitute the product of an individual member or a group, in a specific instance or at the end of the interaction (Activity Analysis tool/ModellingSpace, Dimitracopoulou et al. 2002).

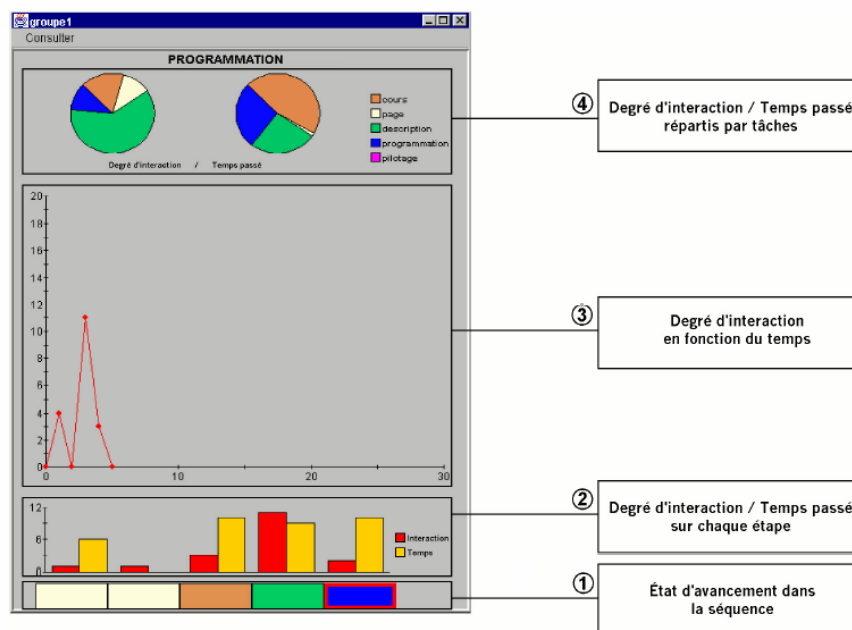
- “the number of entities of each specific type” (Objects ratio/ Collide/ Gabner et al, 2003).

Others Indicators refer to the process of the activity/ task, such as:

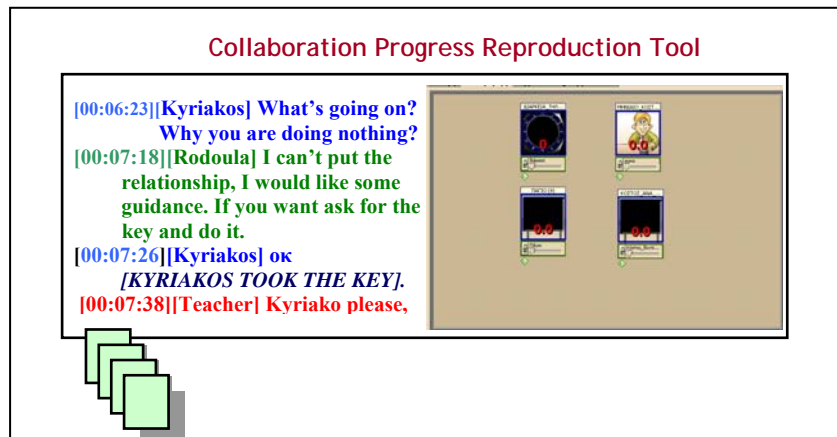
- the “phases of a learning activity session” (Despres, 2002; Petrou 2004), (see Figures 10 & 11).
- “Average depth level of a discussion tree”, that measures the depth of a forum type discussion (it can be used for the visualization via a graph of the average depth in function of time (e.g. per week) (Gerosa et al. 2005)



**Figure 9. Cognitive Indicators, providing awareness on the features of the interaction product CoolModes, Gabner et al., 2003**



**Figure 10. Cognitive Indicator (addressed to teacher) providing awareness on the process of the activity (low part of the image), Despres 2002**



**Figure 11: COPRET IA tool, presenting the process of interaction, according to phases, defined by indicators on significant actions (Petrou et al. 2004)**

Researchers have conceived cognitive indicators that are presented to the IA tool user, with their values in a calibrated form. For instance the indicator “Creativity”: it quantifies the degree of complexity, originality or richness of ideas implied by the elaboration of the text of each contribution. Thus for instance, elaborating a contribution of ‘proposal’ type requires more creativity than making a comment (in Degree Learning Environment, Barros et al., 2002). Another example of cognitive indicator that provides an assessment of the value is the “activeness of each topic” indicator where the values are presented calibrated in an indirect mode via a metaphor (flower: full bloom, threshold, bud of flower // via a representation of recent frequency of keywords) {Kato et al. 2005). A final example of cognitive indicator, applied in a system for individual use, is the “reaction time in psychological experiment” indicator, that is presented to the user with its value accompanied by the deviation from the theoretical norm (e.g. reaction time) (ZAPs system, Hulshof et al. in press).

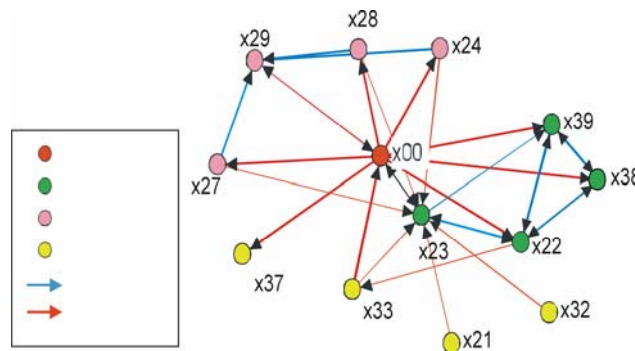
**(B) Social Purpose IA Indicators:** Indicators that have a Social nature or Social purpose, are those that deal with aspects that refer to the communication, cooperation, or collaboration into a small group or a larger community of individuals that participate in the same learning environment. The social indicators refer to various aspects of collaboration that usually influence the quality of collaboration such as: participation level, contribution level, coordination, relations building, etc.

Some researchers consider that those indicators provide mostly abstract views that function as substitute for missing communication and organization cues (Reimann, 2003). However, it seems that social indicators may contribute further than to provide substitutes of the face to face collaboration: showing up aspects of distributed/cognitive group process or structures that could not be depicted with other means.

### Examples of Social level indicators:

There are social indicators that support users in the level of ‘workspace awareness’, others that provide information so as to support the ‘coordination’ among participants, while others evaluate aspects of ‘collaboration’, or describe the actual ‘relation building’ state. Some examples of these cases are the following:

- ⇒ Workspace Awareness of actions of others, in a shared space used by a small or wider: e.g. the indicators “authorship of each material”, and “new files posted”.
- ⇒ Indicators supporting Coordination : - “opinion difference visualization”, Baker et al, 2002, “Activity level indicator” an indicator reflecting the level of activity of groups who use an online pedagogical manager (Jermann 2004). “Coordination” indicator: it shows the degree of intercommunication that appeared within the group members: calculated from three other lower level indicators: Argumentation, Coordination messages, Initiative” (Degree, Barros 2002).



**Figure 12. SNA diagram, and Actors Degree Centrality indicator**

- ⇒ Indicators supporting the awareness on aspects of Collaboration or even assessing its quality, such as: “Contribution level”: indicators refereeing to the activeness of each member, or even indicators implicating also the content of the activity: e.g. the frequency of keywords used by learners, or the content-wise contribution made by each learner to the discussion. An example of indicator that assesses the quality of collaboration is the “Conformity Indicator”: it quantifies the degree of agreement implied by a contribution with relation to the one is linked to, (Degree, Barros 2002).
- ⇒ Relations building: Social indicators that are usually produced via Social Network Analysis, provides (among others) information on relations’ building into a cognitive group (see figure 12). Examples of these indicators are the “Actors Degree centrality” (Martinez et al. 2002), or the “Group Cohesion” one, which shows the



ability of the group to hold their members (the minimal number of participants who when removed from the group, disconnect it completely) (Reyes & Tchounikine 2005).

**Table 5. Purposes of IA Indicators**

Indicators Purpose	cases	Examples, Authors
Cognitive	Process of activity	“Average depth level of a discussion tree”, Gerosa et al. 2005 “number of posts per topic” FLe2, Morch 2004 “Process exposure, COPRET tool, Petrou 2004
	Product of activity	“Objects ratio” Gabner et al. 2003 “Activeness of a discussion topic”, i-bee, Michocuzi et al. 2005, “Creativity”, Barros 2003,
Social	Workspace awareness	Authorship of each material, Activity Analysis/MS New posts from last login, phdbb
	Communication level	Opinion difference visualiser, Baker et al. 2003
	Coordination level	Interactions Level, Schummer et al, 2005
	Collaboration level	“Activity Level”, Jermann, 2004
	Relations Building	Actors Degree Centrality, Martinez 2003, “Group Cohesion”, Reys, 2003.
Affective	Motivation expression	“Individual motivation” over time (one graph per person) ( <i>well being function</i> ) Reimann, 2003 (AIED)
	Motivation enhancement	“status in the society” (gold, bronze, silver member) Hierarchical membership and, Rewarding, Vassileva et all, ITS, 2004

**( C ) Affective Purposes IA Indicators:** Characterizing affect in terms of activity and interaction clarifies that, through emotions one participates more deeply, and personally (for instance in a collaborative critical thinking process). In general effective participation in a discourse and in a learning process requires emotional maturity, - awareness empathy, control, knowing and mapping one’s emotions, motivating oneself, recognizing emotions in others and handling relationships-, (Mezirow, 2000).

The affective dimension is a dimension that recently appears implicitly in IA, but also in Learning frameworks, and learning theories. Affective dimensions appear mostly in collaborative learning context. The affective qualities and abilities are important and significant in relationship building. It is also to be noted that a number of social level indicators could have indirectly affective dimension effects.

### Examples of affective indicators:

There are cases where the individual members indicate/express by own their motivation (*motivation expression*), “Individual motivation” calculated over time and presenting via a graph per person, Reimann, 2003, or “Status in the society” (gold, bronze, silver member) that produce an Hierarchical membership and Rewarding (Vassileva et al, 2004). There are other cases, where the indicators function in a way to directly activate and enhance the motivation of the individuals-participants (*motivation enhancement*), (e.g. motivating them to acquire a better position in an antagonistic situation).

**Current state and new trends:** The research community is in progress to define significant indicators that can be counted in an automated way. There are a lot to do, so as to provide cognitive level indicators, that really analyse the process of the activity (individual or collaborative one) as well as the intermediary or the finally products.

Similarly, as long as the research on the phenomena that appear in group cognition situations, progresses we will have more clear ideas on what kinds of indicators we need to calculate, dealing with social purpose.

Finally, the indicators of affective purpose constitute a new dimension that needs to be further explored.

### **I.3.2.2. Point of view of IA indicators {who’s referred by}**

Which are the points of view on formed cognitive systems during a learning situation? Who is referred by the specific IA output? The learning environment participants, specially when they work in a social context, can not be considered only as individuals. During learning activities in cooperative or collaborative contexts, there are different cognitive systems that are formed. Thus, the question is whether the outputs of available IA indicators, represent these cognitive systems.

We could distinguish four different and general cases of points of view of IA output:

- (a) *individual point of view*: when the indicator measure/represent something on the actions or the product of specific individuals.
- (b) *group point of view*: when the indicator gives information on a specific group. We can distinguish two sub-cases:
  - (b.1) *undifferentiated group*: when the information concerns the whole group, without allowing identifying the ‘contribution, or the ‘role of the members constituting the group

- (b2) *differentiated* group: when the information concerns the whole group, and in the same time, there is the possibility to distinguish the 'contribution of each member of the specific group
- (c) *community point of view*: considering it as group of groups that may incorporates also individuals playing specific roles (such as coordinators, mentors, etc.).
- (d) *society point of view*: constituted by communities

#### Examples of indicators' points of view:

(a) Individual point of view: A number of the indicators of existing IA tools, represent information concerning specific individuals: e.g. "Selected agent contributions", CAF IA tool, (Fessakis et al. 2004)

#### (b) Group point of view:

b1. Undifferentiated group examples: "Active agents": it represents the number of collaborative agents that posted at least one message (in a specific communication channel) in the previous time slot (numerical indicator that is usually visualized via a graph: Interactions-> time> CAF IA tool (Fessakis et al. 2004)

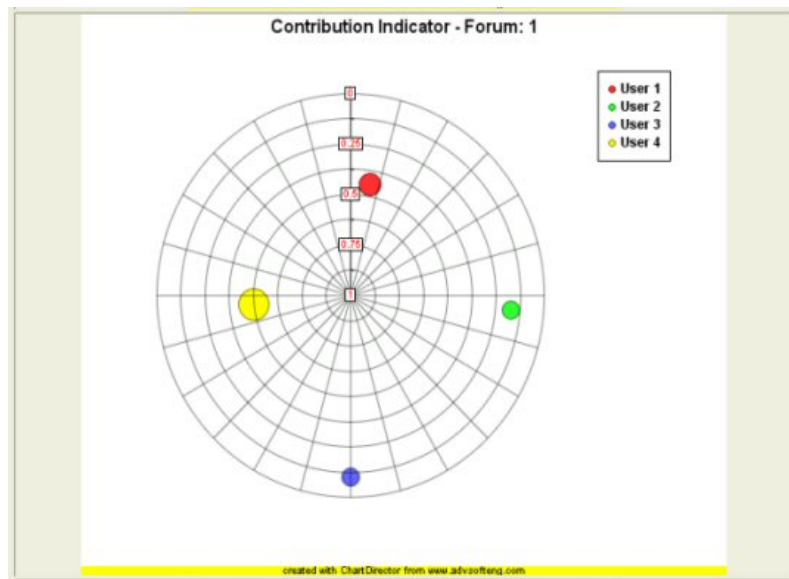
- "Collaboration Level in a group": it's an indicator that is defined via the calculation of intermediary indicators (work amount, argumentation, initiative, conformity, etc), and its output is literal in a range of enumerated values (from worst level to the best expected) (Degree LE, Barros 2002)

- "*Interaction Level*" of a group (see figure 7): It focuses on objects manipulations that are executed in responses to activity feedback of other users' actions. It gives as output numerical values presented as a graph in function of the time. (Schummer et al, 2005)

It is to be noted that often "a single user metric is transformed in group metrics (e.g. when we account the active time of each user, and then the average time of all users). But we have to take into account that this kind of metric does not provide information on the interaction between group members, nor reflect that an individual work rhythm can be affected by the rhythms of other participants (Schummer, Strijbos & Berkel, 2005). Most of the "undifferentiated group" indicators belong to this case.

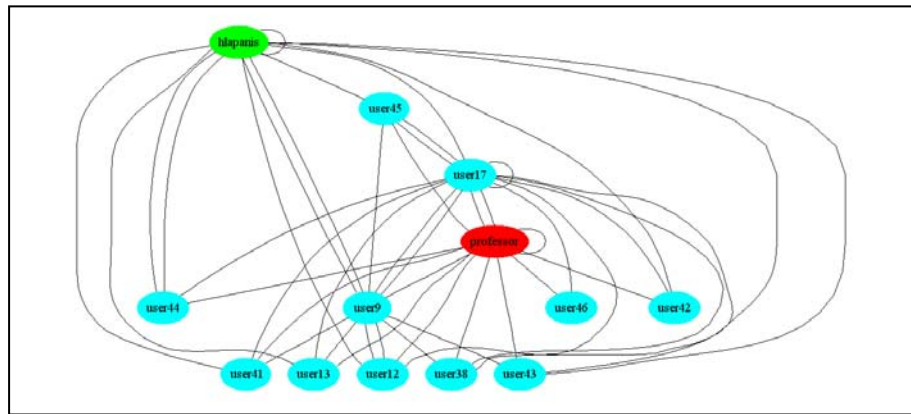
(b2) Differentiated group examples: "Contribution level of each group member". The contribution level of each group member is represented as stars with size dependent on the number of the files that have contributed. The contribution level of

each one is presented in the whole group. The intention of the researchers was to fulfill ‘social visibility purposes’ (Vassileva et al. 2004).



**Figure 13. Differentiated Group Point of View Example: “Contribution in a group”**

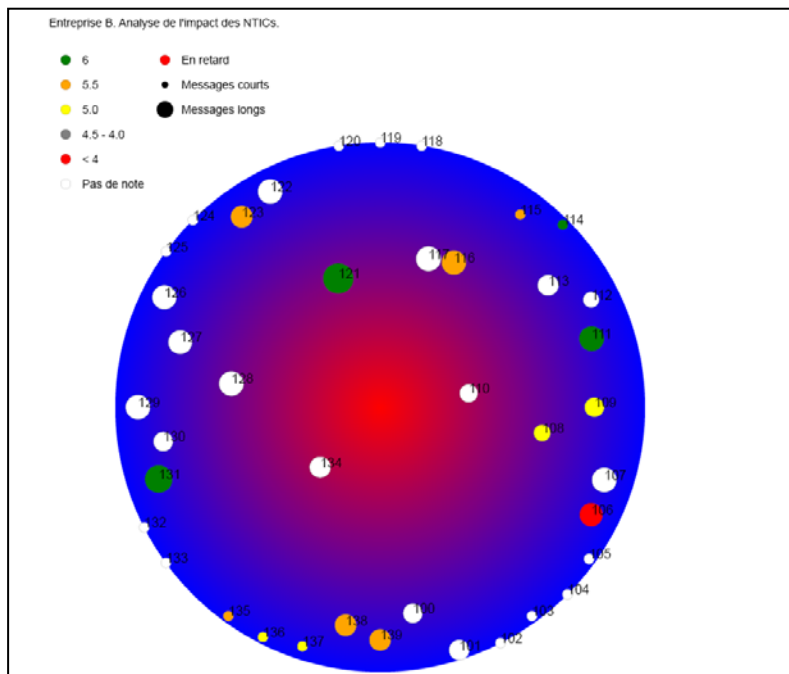
- “*Conversation and action balance*”: (see figure 22) it reflects the balance between the production of problem solving actions and dialogue related actions. The indicator is visualized by a color coded graph: one graph per group is produced. (Jermann 2004) .
- “*Contribution Indicator in a group*” (see Figure 13): A polar chart contains bullets representing the various users. The distance from the circumference of the circle is proportional to the contribution status of the participant, subsidizing the initiation of discussions. The size of the bullet is proportional to the number of message types used. The diagram distinguishes each participant by each circle (DIAS IA tool, Bratitsis, et al. 2005). The users are represented by codes.
- “*Actors Degree Centrality*” (See Figure 14) indicator calculated via the use of Social Network Analysis (SNA) and visualised by sociograms, is a typical example. The indicator represents the number of links that the participants maintain with other participants (Martinez, 2003, Hlapanis et al., 2005). Each participant is represented by a circle in the sociogram. The learners can be represented by codes, and each learner can know only the code that correspond to him(her)self (Hlapanis et al., 2005).



**Figure 14. Differentiated Group Point of View Example: “Actors Degree Centrality” visualised via sociogram**

(c) “Community point of view” indicators examples:

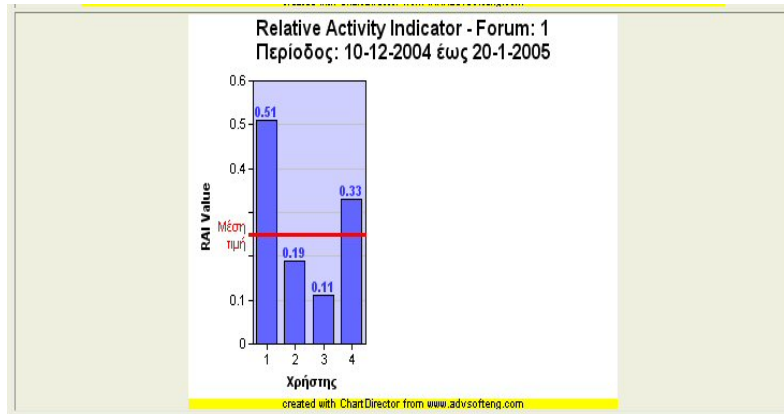
“Activity level Indicator” (See Figure 15): The indicator reflects the level of activity of groups who use an online pedagogical project manager. It shows the contributions of different role groups (students, teachers) to the production of files and messages. The goal of the visual form is to enable a teacher to quickly identify groups which need help or encouragement. The visual form consists of an interactive SVG file. Teachers can navigate from the global view of the class to the local view of a particular group by clicking on the small circles (Jermann, 2004).



**Figure 15: Community Point of View Example: “Activity Level Indicator”**

- *Relative Activity Indicator* (See figure 16): A bar chart is created, showing the activity of a group for the selected time duration as a percentage of the total

activity. Initiation of discussions and use of different types of messages is subsidized. The mean value of the contribution percentage for the selected time is also displayed, thus evincing the most active group. (DIAS IA tool, Bratitsis, et al. 2005)



**Figure 16. Community Point of View Example: “Relative Activity” indicator**

### **Current state and New trends: :**

The cognitive group point of view of an indicator has a significant meaning when we are in collaborative learning activities (with the wide sense of the word). The IA tools, connected or incorporated in social software, produce indicators that most of them adopt only:

- an individual point of view, or
- a group point of view, without an individual distinction

Generally, there are a few indicators that adopt an undifferentiated group point of view, just a few indicators presenting a community point of view, while there are not yet indicators representing a society point of view (see Table 7).

However, we have to take into account that in the CSCL community, it is acknowledged that the current research on collaboration even if tries to analyse the phenomena, and the factors affecting interactions, finally, focuses on measuring the effects on an individual level, neglecting in this way, to really focus on the phenomena appeared in group cognition. Thus, there is a general problem; this of lack of an effective focused view on group cognition.

Often, when the group is viewed, there are indicators that distinguish the group members, while do not present the quality of the group as a whole, and/or the internal interactions and structures. For instance, some of the indicators simply distinguish the members (e.g. Vassileva work based in a “social Validation theory”), based in ‘competition’ intentions.

In any case, what it is missing, by the current IA tools, is the simultaneous adoption of multiple points of views that could be represented by available appropriate indicators.

**Table 6. Indicators Points of view on cognitive systems**

Points of View	Indicators Examples	Authors
Individual	<i>"Selected agents contributions"</i> <i>"Categories of posts per learner"</i> <i>"Number of comments per subject per week"</i>	CAF tool, Fessakis et al. 2004 Chen, 2004 Vassileva 2003.
Group point of view:		
undifferentiated group	<i>"Interaction Level" of a group</i> <i>"Collaboration Level in a group"</i> <i>"Active agents"</i>	Schummer et al. 2005 Barros. 2003 CAF tool, Fessakis et al. 2004
differentiated group:	<i>"Contribution level of each group member".</i> <i>"Contribution Indicator in a group"</i> <i>Actors Degree Centrality"</i> <i>"Conversation &amp; action balance"</i>	Vassileva 2003 DIAS tool, Bratitsis, 2005 SAMSA/SNA Martinez 2003, Hlapanis, 2004. Jermann 2004
Community	<i>"Activity level Indicator"</i> <i>Relative Activity Indicator</i>	Jermann 2004 DIAS tool, Bratitsis, 2005
Society	-----	----

### I.3.2.3. Form of IA indicator output

Taken into account the existing indicators, we can distinguish four general kinds of IA indicator output form: numerical or alphanumerical forms, structures, patterns in a process, and processes exposures.

- (i) *Numerical/alphanumerical form*: There are variables that take numerical or alphanumerical values, and are usually accounted on the base of raw data (logfile): Most of the actually, automated computed IA indicators, are indicators that have as output numerical or alphanumerical values, for instance the values of indicators such as: "number of entities inserted per actor" ("Activity Analysis", ModellingSpace, & CoolModes), "percentage of key-possession in a coordinated shared workspace", etc. Almost all the IA tools produce some indicators of this kind.

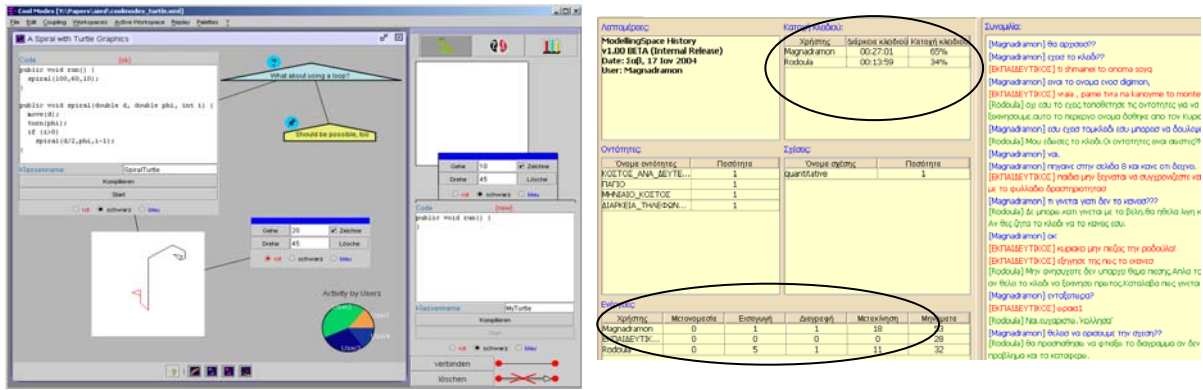


Figure 17: Indicators with numerical values form in: (a) CoolModes, and (b) Activity Analysis tool (ModellingSpace)

- (ii) *Structures*: that mostly concern the interaction product: For instance the output of the indicator “Differences’ Recogniser” accounted internally to the COLER learning environment, that recognizes semantically significant differences between individual and group entity relationships diagrams corresponding to the problem solutions of students.
- (iii) *Patterns*: identified during the process of interaction, eg. patterns of collaborative behavior (see figure 18), (Simmoff 1999), patterns of division of work in a collaborative task of a small group, (Jermann, 2004) patterns of problem solving processes, inquiry processes, etc. A visualization of variable that identify patterns is presented in Figure 19 (Jermann 2004), that illustrates three identified patterns of the indicator “division of labor”. Circles represent subjects; Rectangles represent resources. The thickness of lines connecting subjects and resources represent the proportion of actions performed by the subjects on each resource. The proportions sum up to 1 for each intersection. (a) Task based (b) Role based (c) No division, Concurrent editing. Squares represent resources and circles represent persons.

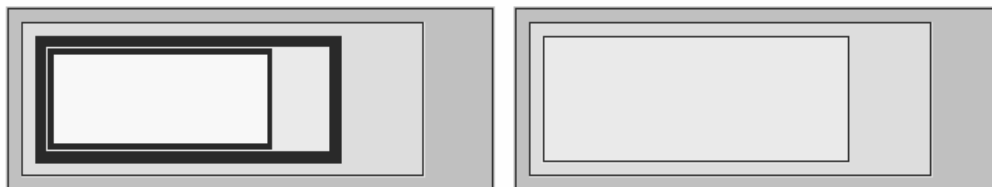


Figure 18. Collaboration Patterns in Discussion threads- Forum [Simmoff, 1999]



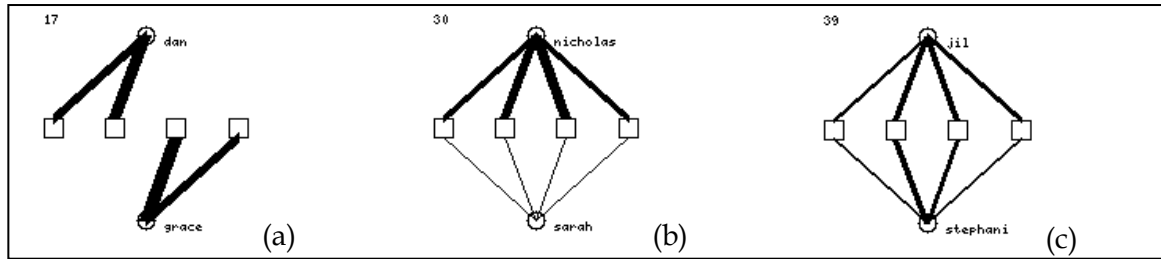


Figure 19. Visualization of the division of labour, in a group of two learners, Jermann 2004

- (iv) *Process exposure*: It concerns sequential presentation of the whole interaction process ('play back' feature, in Baker et al. 2003, & Dimitracopoulou et al. 2002, see Figure 20) or of the process' significant instances (COPRET tool, presenting video-like series of snapshots of interaction process according to criteria of significant actions' episodes, see figure 11). A recent approach is under development for modelling based systems (Bollen et al. 2005), where "Reports" of workspace product phases are identified and presented accompanied with the main actions producing the changes from the one state to the next one. (see figure 21).

Indicators taken values of process exposures kind are particularly useful for: (a) the participants of the interaction process as memory support during reflection phase afterwards interaction, (b) the observers of an interaction process (members that are not directly involved in the activity) such as teachers or researchers, supporting them to put other derived indicators into the context, and thus acquire an interpretative meaning (Petrou, 2005).

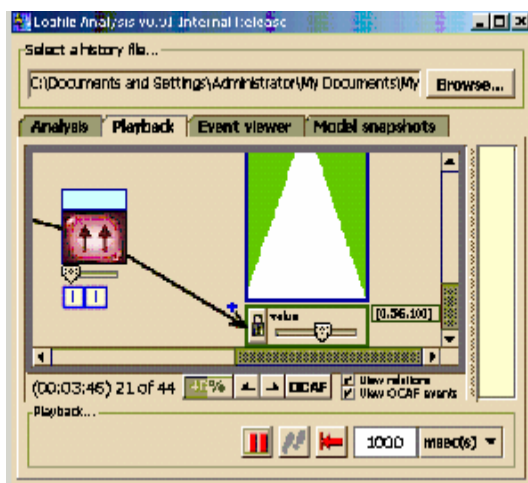


Figure 20. Simple Process exposure (Activity Analysis, MS),

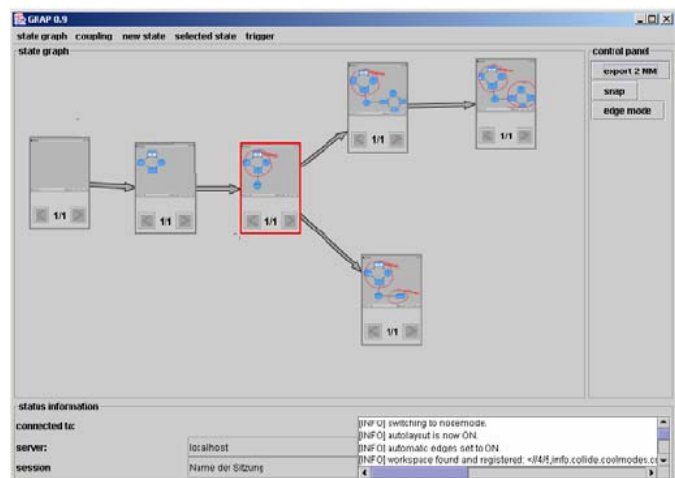


Figure 21 GRAP: Reports Generator (Bollen 2005)

Table 7. Kinds of IA indicators values' form

Kinds of Output Forms	Examples	Authors
<i>Numerical/alphanumeric form</i>	"participation rates, action key possession, interaction level,, etc.	Indicators produced by almost all existing IA tools
<i>Structures of the interaction product</i>	"Differences Recogniser" COLER	Constantino & Suthers 2001
<i>Patterns of processes</i>	Collaboration patterns in discussion threads, "Division of Labor"	Simmoff, 1999 Jermann 2004
<i>Process exposure</i>	video like process via significant actions episodes selection, COPRET, Reports Generator GRAP tool,	Petrou 2005  Bollen et al. 2005

#### **Current state and New trends:**

The actual work is focused on indicators that when processed, produce quantitative information, taken numerical values. What it is actually needed, so as to improve the significance of cognitive or even social indicators is to produce indicators that arrive to show up, significant elements of the interaction process and/or product, that usually means indicators giving as outputs the identifying patterns or structures' features. Additionally, innovative works in terms of process exposure could also have a significant impact in selfregulatory effects.

### I.3.2.4. Level of Assistance of IA indicator

The IA tools provide assistance to their users through the provision of indicators. In fact, the level of provided assistance is directly related to the *status of the value* of their indicators. It is already mentioned that the output of IA tool, regarding a specific indicator may consist of: (a) the value of the corresponding variable, (b) the calibrated value of the indicator, calibration done through a predefined norm, and (c) a decision that taking into account the calibrated value, provides to the user either a kind judgment on the appropriateness of the participants 'behavior' or a clear suggestion on how to continue during the learning activity.

We can distinguish three Levels of Assistance (see Table 8):

- *Awareness*: In this case, the output of the calculated indicator provides just its value (a numerical, or alphanumeric one, a pattern, or just an undecoded process). e.g. "participation rate of the individual user"= 30, "on-line users"=15, (see figure 22) "follow up contributions"=20%, etc. The users of IA indicator of this category have to estimate by themselves the appropriateness of the value, (if this estimation is necessary), eventually comparing this value to their tacit or explicit 'norms' that they suppose or know from the learning context . It is to be noted that there are indicators where the value itself is sufficient, without the need to be assessed, e.g. when the indicator provides just a support on memory (concerning actions of individual participants) or when it provides simple information of the actions of other participants.
- *Assessment*: The indicator output consists of a value that is calibrated, according to a norm usually predefined by the designers of the IA tool, (or by the users themselves in case that the system is customizable). e.g. 'conversation and action balance' =30%-70% while the norm is given in 50%-50%, 'activity level of the learner'= 'sleeping'. The norm can be given in a direct or indirect way, thus providing a direct or indirect assessment. For instance, in the case of the indicator "action-dialogue balance" (Jermann 2004), (see Figure 23), a value of -5 indicates pure action without dialogue, while the value of + 5 indicates pure dialogue without any action and the value of 0 indicates a balance between action and dialogue. However, the users of the IA tool accounting the indicator 'action-dialogue balance' can not see the values themselves, but their visual correspondences produced via the application of a metaphor (color coded car-like velocity meter)

Table 8: Levels of Assistance provided by IA indicator

IA Indicator Assistance level	Subcases	Examples	IA tool or Authors
Awareness	⇒Cognitive awareness  ⇒Workspace awareness (in social environments)	⇒ “Objects deleted”, - Objects types ratio  ⇒ Who is on-line, New actions,	⇒ Activity Analysis/ModellingSpace, Dimitracopoulou et al. 2002 CoolModes, Gabner et al. 2001 ⇒ Phbb, WebCT,
Assessment	⇒Direct assessment  ⇒Indirect assessment (via metaphors)	⇒ Participation Rate= 30% comparing to the 50% of the expected  ⇒ Activity Level: presenting a sleeping or active bee  ⇒ Action-Dialogue balance: presenting with colors, using metaphors of car velocity meter	⇒Fessakis et al. 2004  ⇒Mochizuki et al. 2005  Jerman, 2004
Evaluation	⇒Rating type  ⇒Judgement  ⇒Guiding	⇒ Participation quality per agent: Gold member, Silver member, etc.  ⇒ Collaboration quality: ‘awful’  ⇒ ‘You must read the messages posted by others’	⇒ Vassileva, et al. 2004  ⇒ Barros, 2002  ⇒ Chen, 2004

- *Evaluation*: In this case, the indicator value is calibrated and additionally, there is a strict evaluation on the appropriateness of this value. What it is presented to the IA indicator user is :

- (a) a rating: a grade attributed among the participants. Eg. in case of the value indicating a good participation quality of a member of a forum=> it is attributed to him/her the award of ‘gold member’ (Vassileva, et all. 2004)
- (b) a judgment: “collaboration level”=‘awful’ (Barros, 2002)

(c) a suggestion or a guidance on what the users must do, so as to improve the corresponding value: e.g. “you must read more the contributions of your colleagues”.

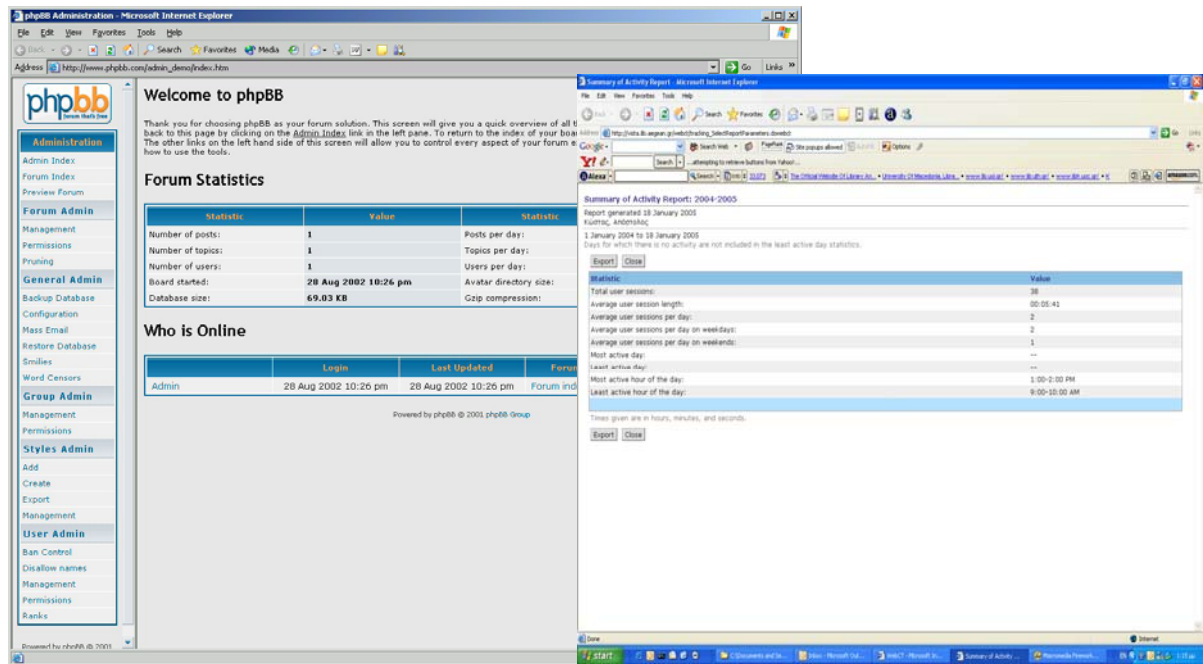


Figure 22. Awareness level Information in the standard Interface of commercial software (phpbb, & WebCT activity Report)

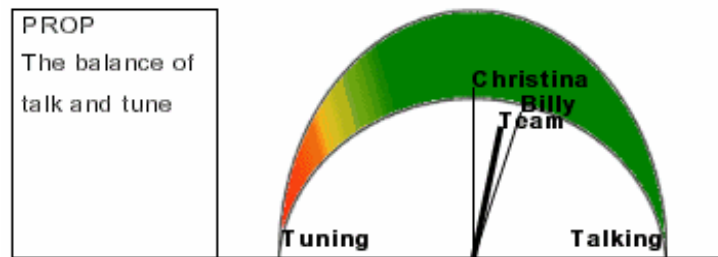
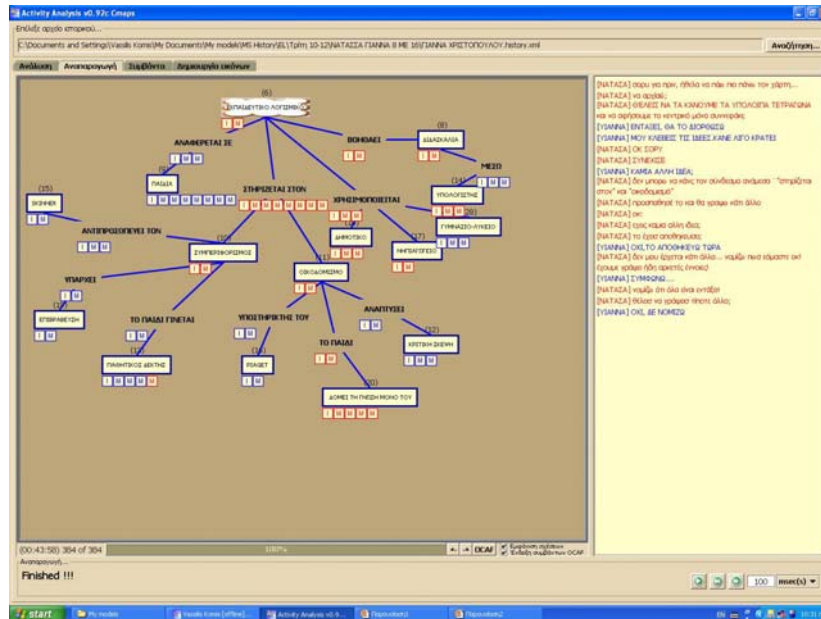


Figure 23: Action-Balance Indicator, Jermann 2004

In every case, it is to be noted that the levels of assistance are not directly connected to the effect that each indicator output may produce in the metacognitive level and then to the selfregulatory actions of the subject. The eventual effect of indicators to IA Indicators users is depending to multiple factors, and it is always to be determined by specific researches.



**Figure 24: Awareness information on authorship (who is doe what and in which order), in Activity Analysis IA tool, of ModellingSpace Learning Environment**

### **Current state:**

The most important part of processed indicators is actually on the level of awareness. Indicators supporting ‘*awareness on the cognitive level*’, offer mostly a support of the memory (regarding actions or events during the interaction process, or the activity itself). Additionally, a significant number of indicators provide “*awareness on a social level*”, in cases where the learning activity is a communicative, cooperative or collaborative one. It is the kind of indicators that are the mostly developed, in CMC tools, and collaborative environments (CSCL or CSCW), that is often due to the need to (a) provide a substitute of missing communication and organizational cues, (b) support awareness of the multiple actions and contributions from a usually important number of participants in such environments.

Actually most of social awareness indicators, are presented in the standard interface of a shared workspace .providing information for instance on the ‘on-line users’, ‘authorship’, ‘new files uploaded’, etc. It is this level of IA indicators which are currently incorporated to standard features of well known environments, as it is the case of “phpbb” providing information on Number of posts, Number of users, Database size (see Figure 22), or the “WebCT” platform, providing information on Most active day, Most active hour per day, Average users per day, etc. These indicators are often identical to the indicators called “workspace awareness indicators”. For an extended and complete state of the art, as well as design principles and guidelines on workspace

awareness, the reader could study the paper of [Gutwing & Greenberg, 2002] as well as the whole related special issue of "CSCW international journal, (No11, 2002).

**New trends:**

The current developments have focused on the production of indicators, offering a level of awareness. A number of systems (following the tradition of Artificial Intelligence) provide assistance in the level of *evaluation*. Whether and when it is really needed to provide assistance in the level of evaluation is a matter of further subtle research (according to scenarios of use, users' profiles, learning activities, etc).

During the next years, it is expected that more indicators providing an *assistance in the level of 'assessment'*, will be produced, due to the progress of the research permitting to calibrate the appropriate indicators in specific contexts).

Additionally, it is expected that more explorations will be done in the area of indirect presentation of the norm, using metaphors (such as sleeping or active bee, or flowered tree, etc), that seems to be specially useful for IA tools users of young ages.

Finally, taken into account that the needed indicators and the norms are influenced by various factors (the learning activity itself, the students' settings, the pedagogical context, etc). the possibility to provide *external inputs for norms definition*, via *customizable tools*, could allow a more extensive use of the same IA tools.

### I.3.2.5. IA indicators variations and combinations of indicators: towards visualizations

In most of the cases, what it is presented to IA tools' users is not the static values of indicators, but their variations. In order to discuss on these aspects, it is significant to analyse firstly an important relation of IA Indicators, this regarding the variable of Time.

#### A) Variations regarding the Time dependence of IA Indicators

Generally, we can distinguish the IA indicators in time dependent and time independent ones:

- (a) *Time dependent Indicators*: there is a number of indicators that are strongly related to the time: such as participation rates, interaction level, activeness of actors, activeness of a discussion topic, etc. and we measure them in function of the time (in usually predefined time slots: such as seconds, minutes, hours, weeks,). Often the time dependent indicators are presented to the IA tool users via a graphical representation of their values variation in function of the time (see figure 25).

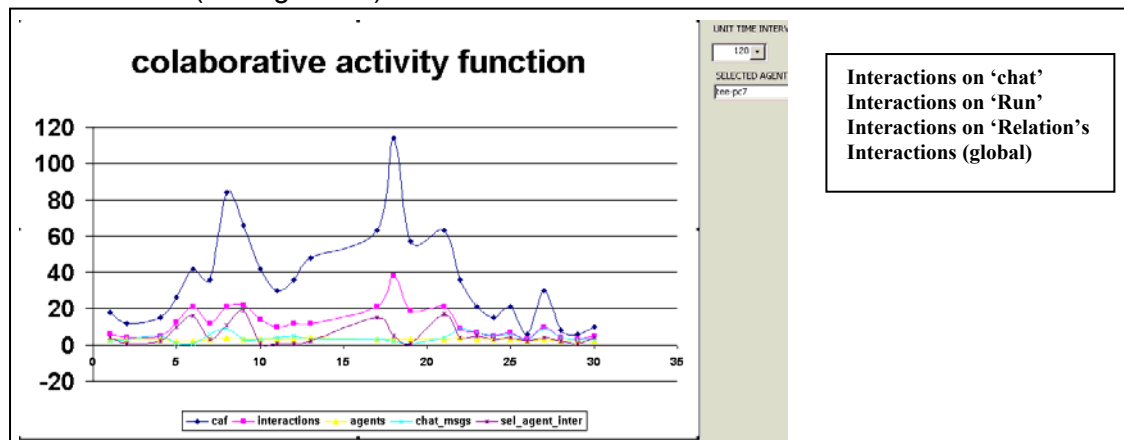
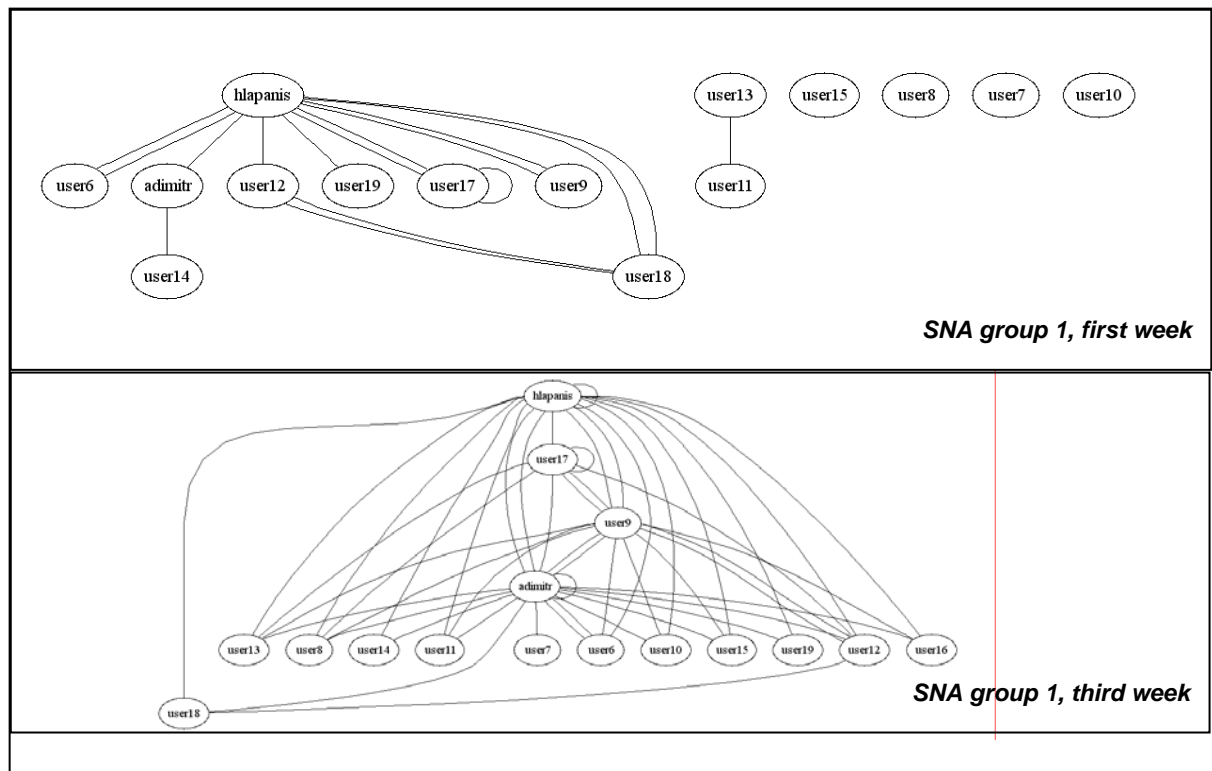


Figure 25. The time dependent indicator of “Collaborative Activity Function, in CAF tool

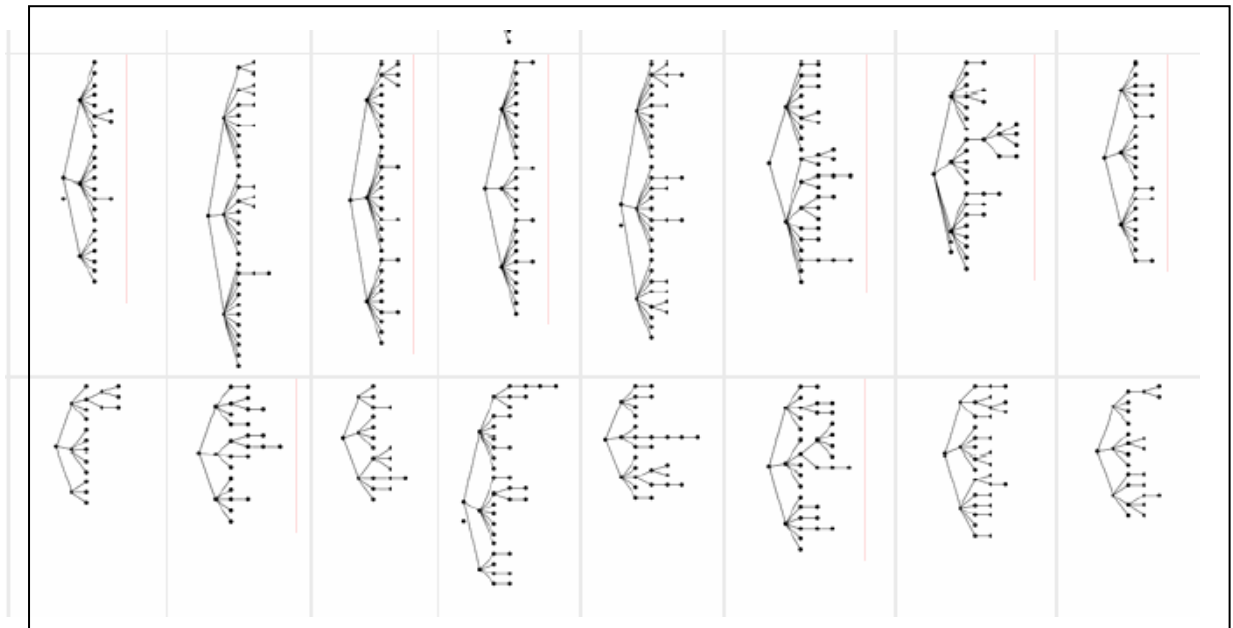
- (b) *Time independent indicators*: There are indicators that we could say that are independent of time, (at least in a first level). It concerns mostly the indicators that by nature have the intention to assess the quality of the process or the quality of the interaction or the collaboration product, and thus there is not a meaning to calculate them in short time slots. However, even for ‘time independent indicator, it is important to:



- Always indicate the time slot or the time period during which the indicator was calculated (regarding the whole interaction duration). Often researchers neglect to indicate these time periods (e.g. when they define sociograms, when they count the message categories, etc.),
- Take into account and study the changes that appear in this kind of indicators in different periods of the interaction, (e.g. in different periods of an asynchronous collaboration process, or different sessions of problem solving). The comparison of the values of these indicators are usually very fruitful in terms of interpretation (see examples in figures, 26, 27). The IA tool i-bee (figure 30) give the possibility to present to the users, the evolution of the whole state of the interaction, in various time slots (e.g. weeks) (Mizochuci et al. 2005)



**Figure 26: Evolution of SNAs in different time periods, Hlapanis et al. 2005**



**Figure 27. Evolution of Forum based discussion depth trees, in different periods of time, Gerosa et al., 2005**

**Current situation and new trends:** Currently, IA tool designers present mostly the time dependent indicators, to the users. However, it may be significant for selfregulatory purposes to work more and exploit the comparison of the same indicators in different periods of time (for the same group), as well as the evolution of time independent indicators in different time periods. Very few IA tools present actually this information and support the needed functionality, so as to be easily available to the IA tools users (participants or observers).

### **B) Categories of Variations and Visualizations of IA indicators**

There are three main types of indicators variations, as well as corresponding visualizations.

- (i) *Visualisations of indicators in function of the time* , that corresponds to typical graphs (see examples in Figures 28a & 28b).
- (ii) *Covariation of two variables*, in a specific time moment, or in a specific time slot. (see example in Figure 10, which visualise the covariation of two variables: action-dialogue rates in a specific time slot).
- (iii) *Simultaneous representation* of a number of variables (not necessary covariation), where the state of a number of indicators are situated in the same timeperiod . Usually, it's a number of complementary indicators that are mapped in the same representation, visualising in this way the state of an individual or a group (representative examples are shown in Figures 29, 30, & 31).

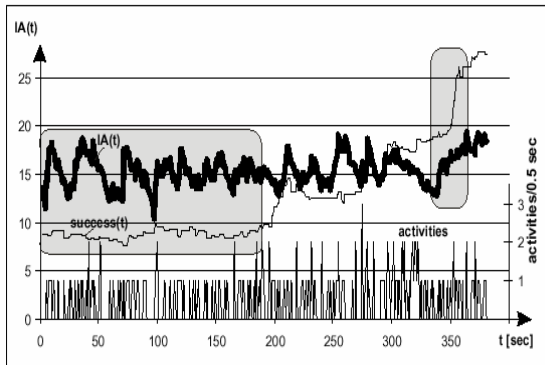


Figure 28a. The Interaction Value  $IA(t)$  (Schummer et al 2005)

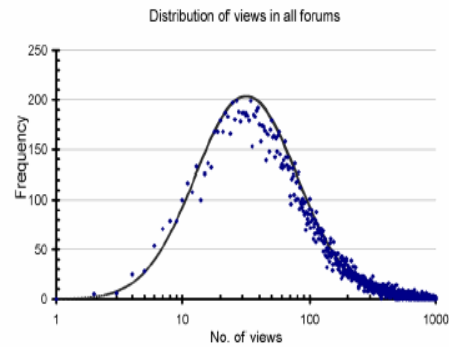


Figure 28b. Frequency distribution of views for messages posted around a given topic, Yeung, 2005

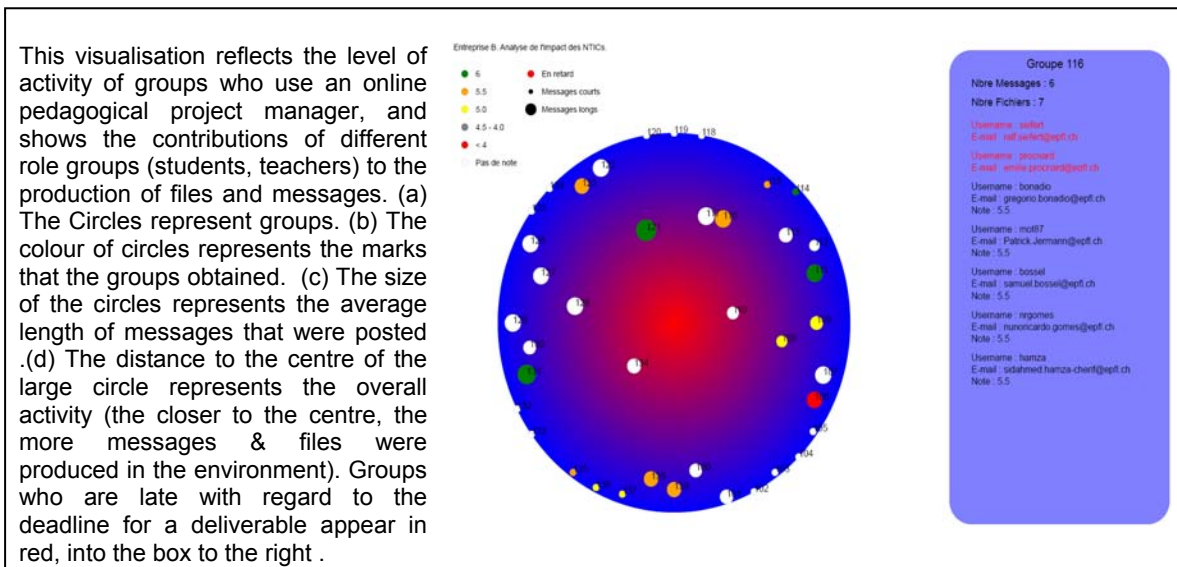


Figure 29. Visualisation of multiple indicators associated to a pedagogical project manager environment (Jermann, 2004)

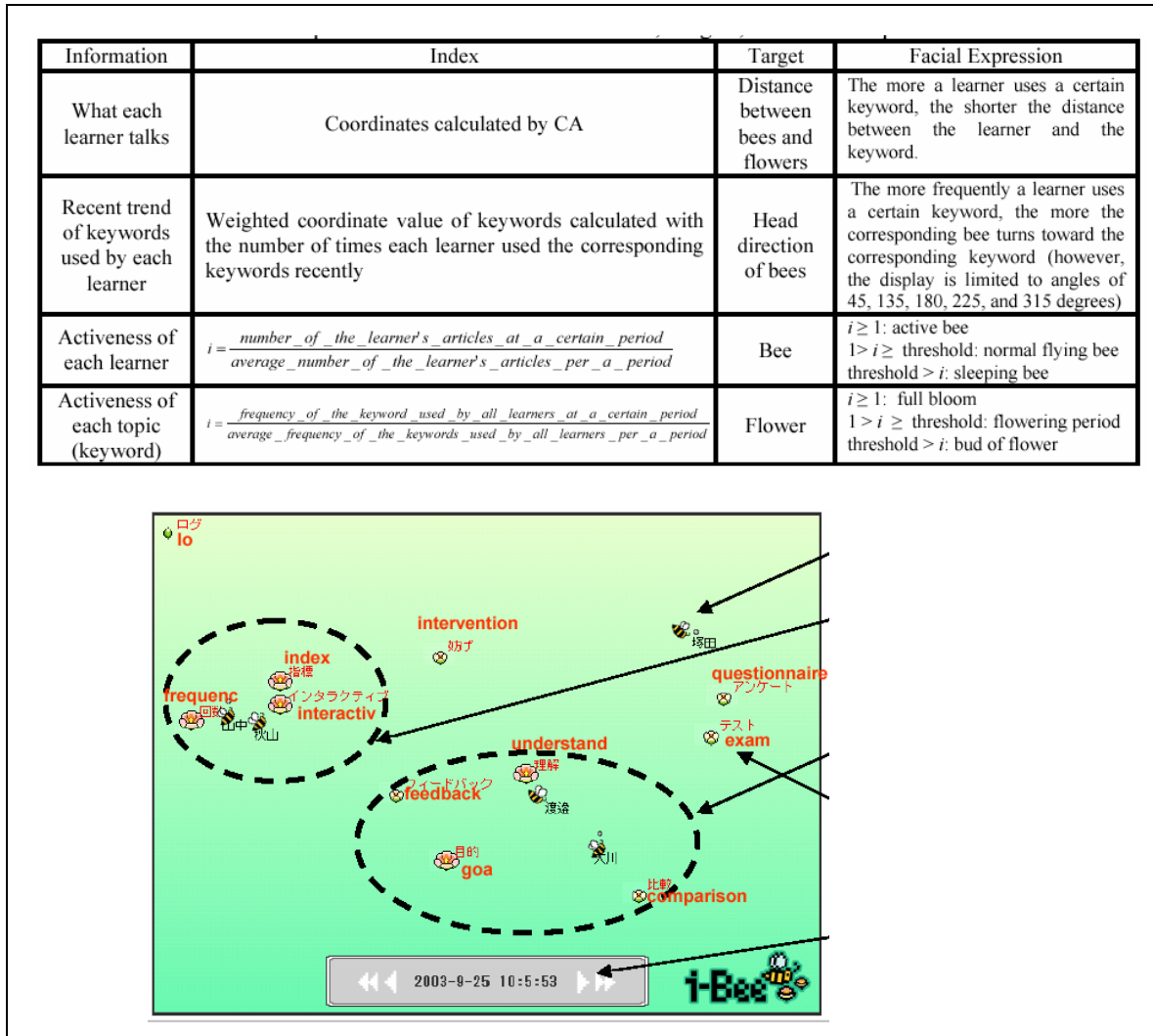


Figure 30: Multiple variables simultaneous visualization: Correspondence analysis diagram, and metaphors used for indicators values, in i-bee tool, Michocuzi et al. 2005

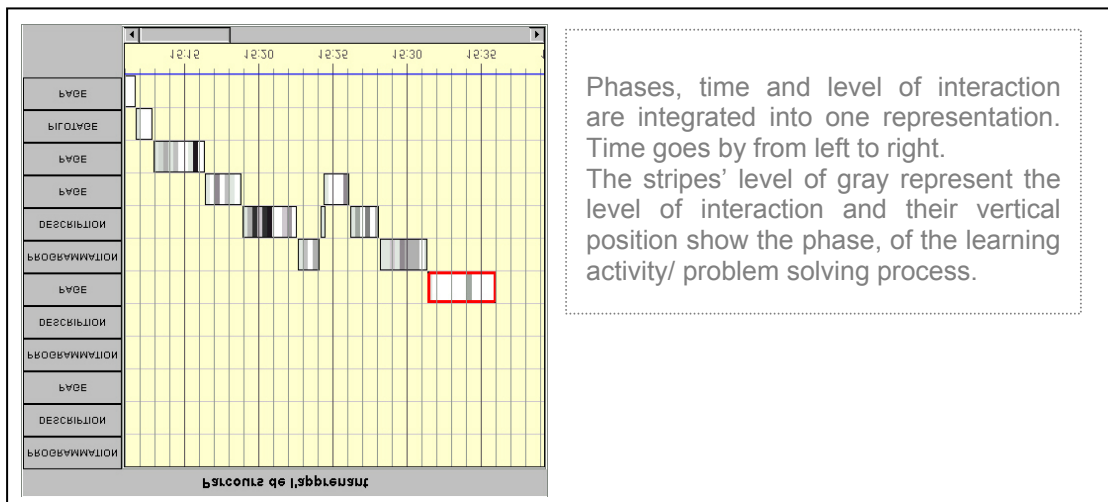
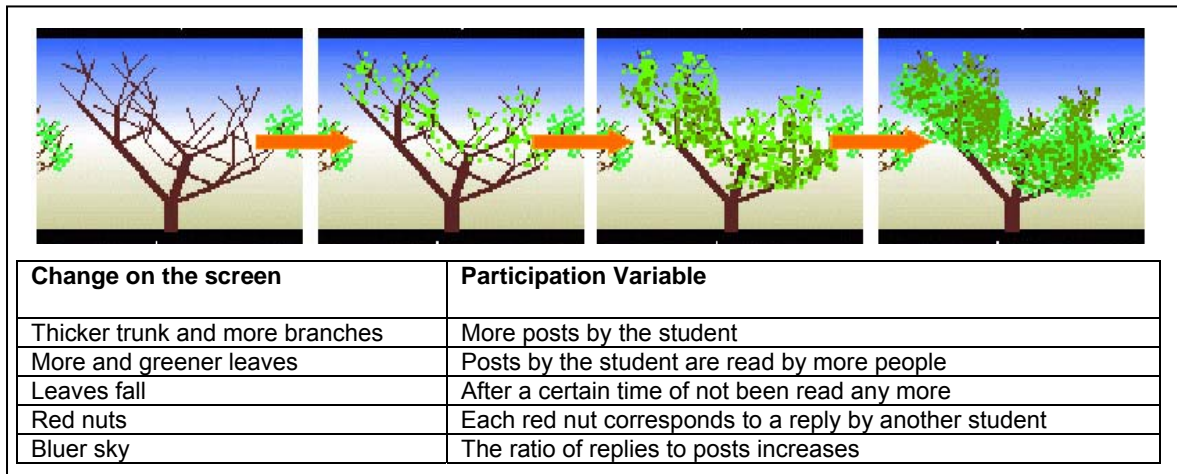


Figure 31. Visualisation of multiple indicators, addressed to teachers (Després, 2001)



**Figure 32. Visualisation of multiple indicators using metaphors: e-tree IA tool (Nacahara et al. 2005)**

### **Current state and new trends:**

Actually, there are mostly time dependent visualizations that are graph representations in function of the time.

Recently it has started to appear two new promising tendencies :

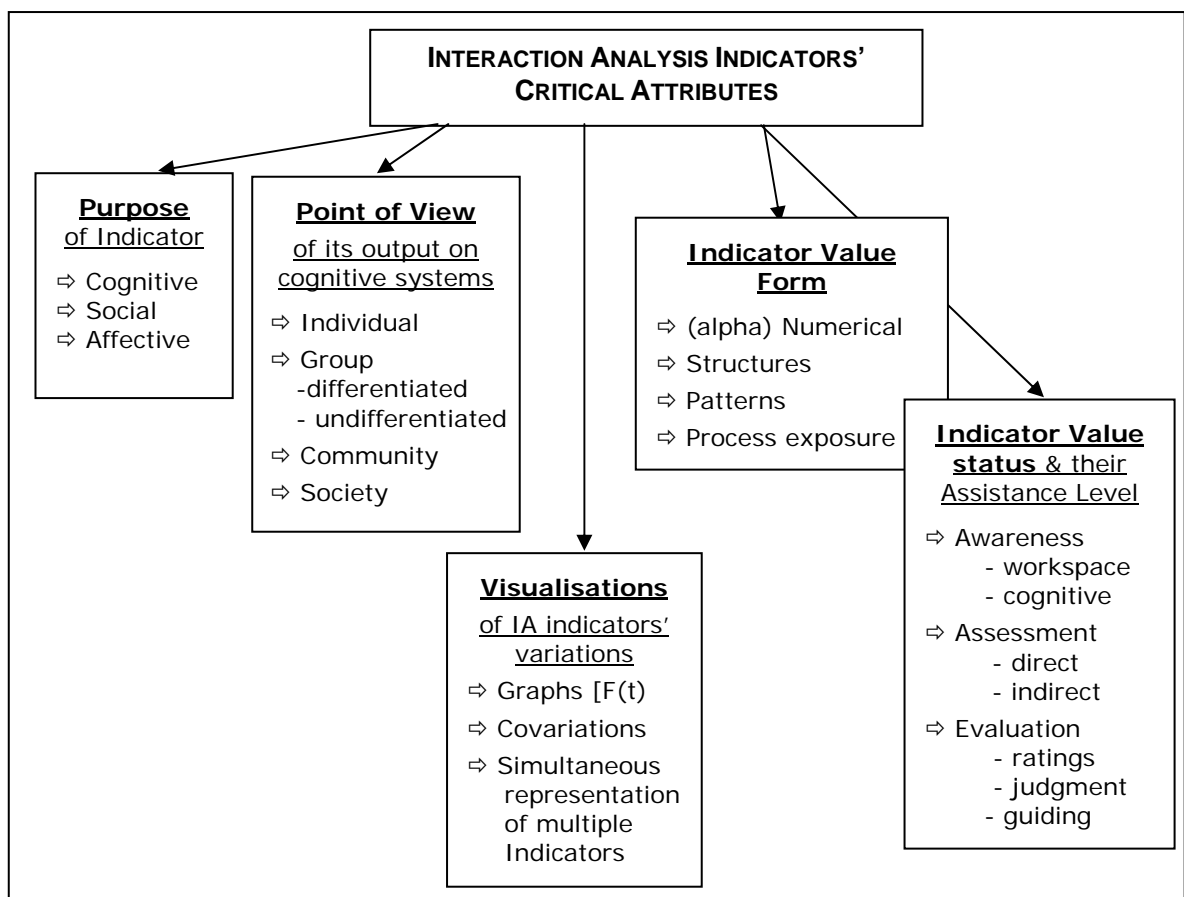
- ⇒ The visualizations that incorporate simultaneously a number of indicators as well as complementary information: This kind of visualisations offer the possibility to have at a glance a whole picture of an aspect of the interaction, something that is very useful as it was shown by related research ( Petrou, et al. 2003, research focused on teacher needs, related to IA tools for every day school activities).
- ⇒ The use of metaphors in the variables values: A good metaphor could provide a nice frame for the simultaneous visualization of calibrated values of a number of indicators.

Finally, it seems that the visualisations of social relations needs to be further explored, so as to identify an appropriate variety. Actually, there are mainly Social Network Analysis (SNA) diagrams that are used.

### I.3.2.6. Conclusions

The analysis of the state of the art on IA tools, go through a detailed analysis in terms of IA indicators that they produce. For this reason, a number of complementary questions were posed: (a) Which are the actual purposes of IA indicators? (b) Which are the points of view of IA indicators and which cognitive systems are referred by a specific IA output? (c) Which are the main actual forms of IA indicator values? (d) Which are the levels of assistance provided by each IA indicator? (e) How the IA indicators' variations and co-variations are represented and how they are visualised? How the dependence of IA indicator by the time-variable is considered?

The above questions were explored via the study of the actual IA tools, and deal with a number of critical attributes of IA Indicators: the purpose of each IA indicator, the point of view of their output, the form and the status of their values, as well as the representations/ visualizations of their variations in function of other variables.



**Figure 33: Critical IA Indicators' Attributes and their current values**

The Figure 33 presents these critical IA Indicators attributes, as they were identified on the base of current developments as well as theoretical considerations, and summarize their actual values, The analysis and discussion on these aspects allowed us to describe the state of the art on IA indicators, determining the current state as well as the new trends, and thus figuring out the actual scientific achievements as well as the new needs for further developments.

First of all, as far as the *purpose of available indicators* is concerned, the research community is in progress to define significant indicators that can be counted in an automated way. There are a lot to do, so as to provide cognitive level indicators, that analyse effectively the process of the activity (individual or collaborative one) as well as the intermediary or the finally products. Concerning the social indicators, researchers have indicated a number of related indicators, during the last years. However, as long as the research on the phenomena appearing in group cognition situations progresses. we will have more clear ideas on what kinds of indicators we need to calculate, dealing with social purpose. Finally, the indicators of affective purpose constitute a dimension that needs to be further explored.

As regards the *point of view of an IA indicator on participants' emergent cognitive systems*, it is a crucial feature of IA tools that deal with data produced in social contexts. The existing IA tools, connected or incorporated in social software, produce indicators that most of them adopt only: an individual point of view or a group point of view, with individual distinction. Often, when the group is viewed, there are indicators that distinguish the group members, while do not present the quality of the group as a whole, and/or the internal interactions and structures. In any case, what it is missing, by the current IA tools, is the simultaneous adoption of multiple points of views that could be represented by available appropriate indicators.

As far as *indicators value' form* is concerned, the actual work is focused on indicators that when processed, produce quantitative information expressed in numerical or alphanumerical values form. What it is actually needed, so as to improve the significance of indicators in a cognitive but also social level, is to produce indicators that arrive to show up significant elements of the interaction process as well as of the interaction product; that usually means indicators giving as outputs the identified patterns or structures' features.

As far as the *status of the indicators value* is concerned, actually, the most important part of processed indicators provide an *assistance* on the level of '*awareness*': They support mainly individuals or group/community memory or providing a substitute of missing communication and organizational cues in social environments. Especially, the workspace awareness is already fulfilled (partially or completely) in a number of commercial software and research prototypes.

In fact, in order to conceive indicators providing an assistance on the level of '*assessment*', it is needed to progress on the related research allowing to: firstly to identify the appropriate indicators, secondly to calibrate them in specific contexts, and maybe thirdly to conceive and use appropriate metaphors so as to provide indirect assessment for the young IA tools users. Finally, whether it is needed to focus our efforts and provide assistance in the level of '*evaluation*' is a matter of subtle researches questions as well as underlying theoretical/ pedagogical considerations.

Finally, it is to be clarified that usually what it is presented to IA tools' users, is not the static values of *indicators*, but their *variations*. In most of the cases, the indicators are presented, as graphs of the indicator variable in function of the independent variable of time. Two new promising tendencies have appeared recently: (i) the *visualizations* that incorporate simultaneously a number of indicators as well as complementary information, offering the possibility to have at a glance a whole picture of an aspect of the interaction; (ii) The use of *metaphors* in the variables' values: they provide in an indirect mode a strong assessment, that may consequently have a strong effect. This kind of visualizations seems to be crucial, especially, in the cases of young users of IA tools (students). Additionally, it seems that visualizations of social relations needs to be further explored, so as to identify an appropriate variety.



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## II. State of the Art on Interaction Analysis Methods

### II. 1. Analysis Methods of Cognitive Indicators

*Andreas Harrer, Lars Bollen, Astrid Wichmann*

In this section we will present indicators characterizing cognitive aspects of learning in computer supported learning environments. Since we focus ourselves on issues related to self-regulated learning where the learner activities are mostly important, we restrict this elaboration on indicators suitable for constructivist and scientific inquiry learning environments. Cognitive indicators can be defined both for the behaviour of the learner, such as the strategies the learner uses to explore a phenomenon, and for the reflection of the learner or the teacher to understand the learning process. We will discuss now representatives of both categories of indicators and the IA methods that are used with an outlook to alternative methods where appropriate.

#### II.1.1. Indicators referring to Learning Strategies

Learners may use a variety of different strategies when given a problem that requires scientific or strategic practices. Some are based on systematic premises of exploring the problem at hand, while some are based on motivational disposition of the learners. Both strands have been followed in recent research activities to understand the effects of behavioral aspects of metacognition in inquiry learning.

##### **Control of variables strategy (or VOTAT “Vary one thing at a time”)**

This strategy is a typical behavior occurring when students systematically explore the dependencies between variables and the effect of modifications of the variable values. Understanding the effects by isolating the changes, i.e. resetting all variables to a neutral value and changing one variable in a controlled manner or modifying one variable between succeeding experiments, shows a higher level strategy characteristic for scientific inquiry. This indicator is especially well suited for simulations and operational models, where different variables can be identified clearly and modified accordingly. Examples for computer environments that offer these kind of inquiry learning are CoLab (CoLab, 2005) and other applications allowing simulation of dynamic systems (Strobel, Hung, Jonassen, 2006). Recent research on defining and

using this indicator has been presented in Wirth et al. (2005) and the follow up work in a Graduate Program for Research in Scientific Teaching.

### Raw data

The indicator is based on the participant's actions in the learning support environment, and in more detail in the actions concerning the experimental space. Each action is logged with the values of all independent variables. Depending on the design of experimental space these values may be changed by textual input, sliders or choice elements (buttons, choice lists).

### Data Processing

While processing the data, two situations characterising the VOTAT strategy may occur:

- all independent variables but one are set to a initial (“zero”) value, thus the one changed value represents the action of understanding this one influence factor; this situation can be identified independently of other learner actions, thus it is easy to detect by querying or matching a pattern
- given a previous experiment/situation the considered situation exactly differs in the value of one independent variable (“ceteris paribus”); this has to take into account sequences of actions thus also considering relations between learner actions

In the work of Wirth et al. (2005) the identification of these situations have been realized by feeding the logs into a spreadsheet and querying with proprietary scripts. In recent work the logging has been modified to be in a structured XML-based format which provides a wide variety of other approaches of identifying these situations, such as in (Harrer et al., 2005) and also conversions into other formats using query engines or data mining techniques.

### Visualization

At the moment the indicator has been mainly targeting the researcher and teacher of scientific inquiry processes. Thus visualization was a minor issue, using standard means of the diagrams provided within the proprietary application. With the above mentioned approaches more sophisticated visualizations, such as timelines with highlighted situations and their characteristic values, can be achieved, that might also be suitable for feeding the indicator back to the learner after the learning or even at runtime.

## Interpretation

The indicator mainly signals the situations characterising the VOTAT strategy, thus the interpretation if the learner uses higher-level metacognitive strategies is on the target user of the indicator, at the moment the researcher and teacher. The indicator has been validated in the large scale study PISA 2003 with 747 students of age 15.

## Inquiry Method

Inquiry method has been successfully implemented in several learning environments (White, 1998; Wichmann, 2003) to continuously engage students in a cycle of scientific experimentation. Through systematically formulating a hypothesis, setting conditions and conducting a experiment and elaborating on the experimentation process, students are encouraged to use metacognitive strategies such as planning, evaluating and monitoring (Brown, 1984). The verbal representations that evolve through the experimentation process allow researchers to analyze students' knowledge structures as well as metacognitive indicators such as monitoring statements (Chi, 1989) or evaluating statements (Wichmann, 2005).

## Raw Data

These metacognitive statements are embedded in self-explanations, which have been formulated by the learner during the inquiry process.

## Data processing

In the case of Wichmann et al. the explanations were logged and classified according to the phases of the inquiry process in which the explanation occurred (e.g. Hypothesis).

## Learning Diary

Recently efforts to support metacognition as part of self-regulated learning have been focusing on implementing learning diaries in school and university settings. Students are asked over a period of e.g. a semester to track their learning process. This can include questions such as “how much have you learned today”, “what are you planning to learn”.



## Raw Data

In Winter (2005) students use a web interface to produce the learning diary. These data is saved in a database and can be retrieved according to the categories that have been determined in the categorization schema.

Both for Inquiry Method and Learning Diary the understanding of the self-explanations is critical for interpreting the learning process. Thus language processing techniques might help to improve the support of metacognition by (pre-)processing the explanations and classifying them automatically. Typical techniques that can be used for that purpose will be discussed in the summary of this section.

### **II.1.2. Indicators referring to Reflection of the Learning Process**

Reflection is a critical activity for evaluating if the learning process was guided by some plan. Thus indicators and tools supporting reflection on learner's and teacher's side to understand what happens or what happened play a major role for the learning process. In complex learning environments that adapt the concept of Dual Space (Klahr and Dunbar, 1988) this support is usually even more difficult, since the separation in two distinct working spaces, the hypothesis space and the experimental space, makes an orientation of the interrelations between the two spaces challenging. We will present techniques and tools promoting reflection of the learning process by raising the awareness of relations between these different types of activities.

*Replay with explicit linking between the spaces:*

Synergo (Avouris et al., 2004) is a collaborative modelling environment that can be used for building flowcharts, entity-relationship diagrams, concept maps, data flow diagrams etc. For communication and coordination issues, Synergo provides a chat tool and a floor control mechanism. Thus it is a typical collaborative application following the dual space principle. Integrated into Synergo, is an action analysis tool based on OCAF (Avouris et al., 2004). This analysis tool allows for a posteriori analysis of collaborative aspects. An important feature of Synergo's analysis tool is the option of manually linking chat messages to objects (and therefore to actions that are related to these objects) to refer messages to objects in the modelling space. This can be used by the learner to reflect on the process and the dependencies of his actions. From this manual processing during the reflection, different collaboration indices can be derived, e.g. a "Collaboration Factor" (see next section) and a "Evolution of Actors activity". All these

analysis facilities are based on raw data like an action log and a chat log (both in XML representation), combined with an underlying typology for semantic categories. The interpretation of the modelling actions can be automated by a table assigning categories to action types, while a shallow automated analysis can be conducted using the sentence opener mode in Synergo with categories assigned to each phrase.

### **Protocol/Report Presentation for Reflection**

There are different approaches to be found in the literature about the use of protocols or reports of the learning activity for the purpose of stimulating reflection about the documented learning process. The degree of processing and format of representation of these techniques may vary widely, from merely displaying logfiles to capturing graphical images to more sophisticated abstraction and classification mechanisms. They all share the property, that the interpretation is facilitated by the system, but ultimately exclusively is on the user's side as the metacognitive reflection process.

In the Pedagogica framework for learning tools, that provides a variety of different topics, such as Mendelian genetics, the user actions and answers to tests are logged (Buckley, Gobert, Christie, 2002), in the recent versions in an XML representation. After the learning sequence the student can review her learning process by inspecting these logs either in the raw format, in a full text (non XML) version, or with some computed properties, such as the "elaborateness of free text answers" by counting words per answer.

In (Harrer, Bollen 2004) an approach for abstracting and classifying raw data for interpretation and reflection purposes is described. The raw data that is used in this approach originates from the synchronisation middleware, which is used to couple several instances of collaborative modelling tools. This raw data consists of single synchronisation messages that describe events like "object XY created", "object XY modified" or "object XY deleted". An object in this representation can be anything from a message in a chat, a place node in a Petri Net or a handwritten stroke. With the help of a typology, these messages can be transferred to a higher level of abstraction like "simulation relevant", "cosmetically" or "meaningful". This classification will vary dependent on the domain in which the user action took place (e.g. modelling System Dynamics has different categories than creating a concept map etc.).

In a prototypical implementation, these classified and abstracted user actions are fed back to the user on-the-fly by presenting textual descriptions of the classification types. Although this classification turns out to be a light semantic interpretation of the original raw data, the user still has to reflect on his actions and to infer the meaning of his actions herself.

### II.1.3. Summary

Up to now most approaches for support of metacognitive aspects use relatively simple analysis methods, which restricts the usefulness of the computer-produced indicators and puts the major part of interpretation on the user of the indicator. Yet there is obviously a great potential in utilizing more sophisticated analysis methods for classifying actions or textual contributions to (partially) relieve the user of having to make a complete content analysis and coding of the learner actions. Dönmez et al. (2005) show that automatic classification was utilized successfully for coding processes of argumentative knowledge construction, which had to be done manually before. Latent Semantic Analysis (Foltz, 1996) is one of the approaches that can be used for this purpose; given a proper corpus of texts with associated classifications, which is usually available after some studies with manual coding of the learner explanations/utterances, these techniques usually classify the texts sufficiently reliable to be a help for the interpretation by the user.

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***Wirth, J., Meyer, K., & Leutner, D. (2005). Assessing behavioral and reflective aspects of metacognition. Paper presented at the 11th EARLI Conference, Nikosia, Cyprus. II.2. Social Indicators and Analysis Methods***

***Alejandra Martinez, Jose Antonio, Yannis Dimitriadis***

We present here two types of social indicators. By social indicators we mean those that measure aspects of the collaboration, such as the interactivity of the processes, the level of participation of the users or groups, etc. They are classified into two groups: quantitative indicators based on statistics that provide an overview of the "balance" of collaboration in a group; and indicators that try to measure or visualize the structure of collaboration. We describe them in the following sections, with a brief explanation of their use in the IA methods or tools they support. When appropriate, the description of these IA methods is divided

into the following parts: raw data taken by the indicators; processing; visualisation and interpretation.

### **II.2.1. Quantitative indicators of action balance**

The Synergo system ((Avouris, Komis, Martaritis, & Fiotakis, 2004)) presented in the previous section, and the tool developed by (Fessakis, Petrou, & Dimitriacopolou, 2004), compute the quantitative indexes CF (Collaborative Factor) and CAF (Collaborative Action Function), respectively. Both indicators are quantitative measurements that try to provide a simple and easy to interpret value of the *quality* of collaboration. We review here the different phases and conditions of the IA methods that use these indicators.

#### **Raw data**

Both indicators are based on the participants' actions in the learning environments.

No content analysis is attempted, in order to keep the analysis simple and easy to process and interpret.

CF takes actions on objects, in a format based on the OCAF framework. OCAF defines a model of activity based on a sequence of events defined by time, action, object and type. The basic objects used by Synergo are those manipulated by the users in the shared workspace. In addition, Synergo defines the concept of "abstract object" that can be defined off-line by a reviewer. In the first case, event information is provided directly by the system. In the second case, event information needs a manual pre-processing which would be only suitable for off-line analysis of the interaction.

CAF, as described in (Fessakis et al., 2004) takes as the base data the actions performed by the participants through the different communication channels that are offered by the environment (chat, sticky notes, etc.). In this case, all the data are provided automatically by the system, which allows for a fully automatic computation of the indexes.

#### **Data processing**

Both approaches perform calculations in order to measure the quality of collaboration. In both cases, time is used as a basic variable that allows to account for the evolution of the indicator (and thus, of the quality of the collaboration process).

CF is defined to provide an idea of the symmetry of activity among the group members, this is, the relative contribution of the group members for a specific type of events. It takes a value between 0 and 1. A value next to 1 means that the contribution of each subject to each object is similar, while a value next to 0 means that only one actor contributed to an object. Synergo produces also partial indexes, which are very useful to understand aspects of the interaction, related to the density of occurrence of a type of event in a period of time, or the number of new objects in the shared space in a time interval. We should note that Synergo provides other types of indicators, such as the history of the objects in the system. These indicators have been discussed previously, as part of the cognitive indicators.

CAF computes the participation of the group through the different collaboration channels provided by the system (e.g., chat, sticky notes, etc.) The aggregated factor provides an idea of the amount of collaboration, while partial results (this is, the collaboration activity per channel or per actor), provide results that allow comparing qualitatively agents and means of communication. CAF is proportional to the number of agents interacting, and to the total number of interactions. By combining both aspects (number of agent and total number of interactions) it avoids to consider extreme situations (for example, a unique actor producing all the interactions) as normal ones.

Both indexes have been defined ad-hoc by their authors. The computations are based on simple statistics. The most important feature in their definition is the fact that, as reasoned by the authors, both indicators show coherent results for all the possible cases that can occur in the learning environments they produce.

**Visualization:**

Both CAF and CF are suitable for a graphical display, showing the time evolution of the respective indicators. The tools developed for their visualization not only allow observe the graphs, but also to configure them so that the user can select the agents to study, or the time slots for which the curves should be plotted.

This is very useful if the teachers or user wants to get insight into different aspects of the process.

**Interpretation:**

These indicators are thought to provide an overview of the collaboration features they represent. It is thought that the user should interpret them in the context they have been produced, thus avoiding misinterpretation of special situations.

CAF has been validated in real conditions, showing that it was a suitable support for assessing collaboration, assessing contributions by the students, and choosing points that needed a more detailed analysis.

There is no report of a validation of CF as an isolated indicator, but there are reports of the overall system.

### **II.2.2. Indicators of structural properties in discussion forums**

The indicators that will be discussed in this section try to measure and/or display the structure of collaboration emerging from collaboration through educational forums and alike. In general, these systems show the structure of collaboration by computing or displaying the position of the participants' (actors) and/or topics of discussion so that their interpretation is easier than one provided by a history of events. We will discuss three of them here. First, the "structural awareness" system proposed by (Reyes & Tchounikine, 2005) that adapts social network analysis (SNA) measurements to the specific needs posed by the authors' environments; the one proposed by (Gerosa, Gomes Pimentel, Fuks, & Lucena, 2004) that uses different features of a discussion forum to provide visual information on the interaction, and iBee (Kato et al., 2005), that displays content-aware maps of the activity of the users on a Bulletin Board System (BBS).

#### **Structural awareness**

The system by Reyes and Tchounikine proposes the use of two indicators based on the SNA approach: *status* and *cohesion*, in order to measure the activity at different levels of granularity.

- Status refers to the "prestige" of an actor in a community, and relates not only to his participation but also to the status of the participants which s/he communicates with (Wasserman & Faust, 1996). There are several indexes to compute status, but Reyes and Tchounikine (2005) propose to use eigenvector centrality, because is the only one that establishes the value of a participant status taking into account the other participants' status.

- Cohesion is related to the diffusion of information in a group. The more cohesive, the more the information flows within the group.

The proposal of Reyes and Tchounikine adapt the computation of these indexes to the specific needs of the interaction analysis in learning systems. More specifically, they use a definition of eigenvector centrality suitable for non-symmetric relationships, (which is the case of the links established through discussion forums, like "writes a message"). For the cohesion definition, they apply the original algorithm to calculate the k-connectivity of a group (Wasserman & Faust, 1996) and normalise it in order to compare groups of different sizes and structures of participants.

These two indicators are applied to an IA system that takes actions of the participants on the learning environment (a discussion forum) as the input data and computes them. The indexes are displayed non-graphically, and integrated in a support system for "structural awareness", whose objective according to the authors is to "make salient the structural properties of a group to its participants in order to promote collaborative interactions and allowing tutors the management of learning interactions and tracking collaborative processes. No validation of the effects of displaying this indicator to the users is reported by the authors.

### **Tree-like visualisation structures for a forum**

(Gerosa et al., 2004) describe the tree-like visualization tools they have developed that compute and display the statistics and linkages between forum messages. The three basic features that they use to facilitate the coordination of the educational forums are: message chaining, message categorization and message timestamp. With these three features they build three supporting facilities:

- The message chaining is the base to build tree-form visualisations of the forums. This tree helps to infer the level of interaction among course participants. Based on these chains of messages, the system also computes some statistics, such as the average depth of the forums during a course, and displays it in a graphical format.
- Message categorization provides semantics to the way messages are connected, helping to identify the accomplishment of tasks, the direction the discussion is taking, etc.



- Message timestamp helps to identify the level of activity along the observed period.

In general, there is no unique IA method implied in this system, but a set of supporting features. They are meant to help the teacher to intervene in order to keep the discussion from moving in an unwanted direction (indications and alerts about situations where problems exist and where the discussion is going well).

The strategy of using pre-categorised messages, used by the authors to provide semantics to the analysis, is a well-known approach. It has the advantage of being very simple to process, but it is also well-known the problems arising from a bad use of the categories. No comment regarding this is made by the authors in the evaluation of their system.

## **iBee**

iBee (interaction Bulletin-Board Enrollee Envisioner) (Kato et al., 2005) is a system aimed at supporting participants self-reflection based on a content-aware graph of the activity on a discussion forum. This is achieved by computing by Correspondence Analysis the co-occurrence between learners and keywords in the forum. The steps followed by this IA system are the following:

**Data preparation:** As mentioned, iBee collects data from a BBS (a type of discussion forum). It filters these data to compute the number of occurrences of each keyword in the messages. The keywords are an input parameter, and can be chosen by the researcher, the teacher, or any other user, depending on the situation.

**Data processing:** iBee uses Correspondence Analysis (CA) as a method to display graphically the relationship between individual keywords to the whole. This method computes coordinates for multiple variables (keywords and users in this case), so that co-occurring keywords are displayed close to each other, and they also appear close to the users that wrote them in their messages. This way, it is possible to provide an intuitive view of interrelated words (that could refer to concepts or ideas) and of the users that used them. A good property of Correspondence Analysis is that it does not need large amounts of data, as it is independent from statistical assumptions. This way CA can display the status of an overall discussion as well as each learner's involvement in that discussion.

**Data visualization:** Correspondence analysis provides a set of coordinates to display a set of variables. These coordinates are meaningful by themselves, as

described in the previous item. Besides this, iBee displays actors and topics using different figures, thus providing a more intuitive vision of the level of interactivity of the users. The users are displayed as bees with three different shapes: sleeping, normal, or active bee. The activeness of each topic is represented by three types of flowers: full bloom, flowering period or as a bud. Finally, head of the bee is turned towards the keywords that the user has used more frequently in the last period.

The system is also able to display the evolution of discussion. When the users connect to the system, it displays the evolution of their contribution to the system since the last timestamp.

Interpretation: Experimental evaluation of iBee showed that the users could see their position as bees, and analyse both their change of state, as well as their overall contribution to the whole of the discussion. According to the authors, such recognition and assessment encouraged learners to consider their level of participation at the meta-level.

### II.2.3. Conclusions

The previous section presented the analysis methods applied to compute Interaction Indicators designed to fulfil a social purpose. The presentation was focused on two different and distinguished cases: (a) quantitative indicators based on statistics, and (b) indicators that try to estimate the structure of collaboration. It is acknowledged that actually, there is not a wide variety of analysis methods computing social indicators, while there is a more clear lack on the representation possibilities of structural aspects of social interactions. Moreover, it is to be taken into account that, in the same time, there is a lack of powerful methods of automated analysis of the interaction product (and content), an aspect that incorporates/cover a number of crucial dimensions in group cognition phenomena.

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### **III. State of the art on Research Methods applied to investigate the IA tools effects**

*Vassilis Kollias, Argyro Petrou*

#### **III.1. Introduction**

The aim of this chapter is to review empirical research concerning the use of computer based interaction analysis (CBIA) by students and teachers. The literature review includes articles and relevant references in the Proceedings of the (Computer Supported Collaborative Learning) CSCL 1999, 2001, 2003 and 2005 conferences, the Proceedings of the 7<sup>th</sup> International Conference on Intelligent Tutoring Systems (ITS 2004), the references of review papers (Jermain et al.,1999,) as well as of related workshops (Soller et al, 2002, 2004). It also includes current research done by the participants in the IA JEIRP.

Collaborative learning is one of the most promising ideas for learning and teaching due to social and cognitive reasons. As a result during the last decade a number of systems that support collaborative learning have been designed and implemented and have increasingly used in higher education and in distance education settings. Collaborative learning is effective under certain conditions concerning learning scenarios and collaborative settings. In order to support productive collaboration, computer based interactions analysis tools have been designed and implemented. But although the field of CBIA has attracted a lot of attention on the side of implementing different ideas about possible indicators, research on the side of empirically assessing either the dynamic phenomena when these indicators are available to teachers and students or the change in important educational variables before and after the use of indicators by teachers or students is scarce.

However there are many interesting questions related to the actual playing out of the affordances and constraints that the new indicators present. Different perspectives lead us to different questions:

1. From a phenomenological perspective we should like to know about the experience of using indicators. We would also like to know the users' own requirements about interaction indicators.

2. From an interactionist perspective we should like to know changes in the coordination of the interaction and in organizing the work done inside the classroom and to have sensitive accounts of the production of knowledge that collectively takes place in the classroom.
3. From a cognitivist perspective we should like to know effects for knowledge and effects for the cognitive, metacognitive (especially regulative) competences of students and teachers
4. From a normative perspective we should like to know whether the affordances provided by the indicators are assessed in different ways by different normative orientations towards education.

Some other questions would inform all these perspectives.

1. What are the factors that may affect the degree of correlation between the intended functionality of an indicator and the actual functionality in which users apply it?
2. What difference does it make the degree of explicitness of the interaction feedback? (Indicators may directly refer to the Interaction. Alternatively knowledge objects may be used as intermediaries so that student interaction comes out as a side effect. Finally the software could directly intervene in the dynamics of the interaction through an artificial intelligence agent who affects the interaction and at the same time works as a model for the other participants )
3. What difference does it make if the interaction feedback is provided neutrally or accompanied by some form of assessment? (The distinction between mirroring tools, metacognitive tools and regulating tools that Jerman makes in his dissertation)
4. Can interaction indicators be beneficial by virtue of the aspects of the interaction that they hide rather than reveal through their biased representation of interaction to the users?

From a methodological point of view different perspectives are better suited by different research methodologies.

1. How good fit do we find between the research goals and the methodologies that are used by the different research groups?
2. How confident do the methodologies used make us about the generalizability of the results in other educationally significant contexts?
3. Which perspectives are studied more and which are underrepresented?

Finally

What are other aspects of the intervention are particularly significant, aside the selection and design of interaction analysis indicators for the development of rich learning environments?

## **III.2. Literature Review**

### **1. Nakahara, J., Kazaru, Y., Shinichi, H., Yamauchi, Y. (2005). *iTree: Does the mobile phone encourage learners to be more involved in collaborative learning?* CSCL 2005 Taiwan**

The researchers' goal was to increase student participation in a Bulletin Board System. For this reason they constructed a mobile-phone application called iTree. iTree displayed wallpaper on the learner's mobile phone screen to keep him/her up to date with his/her level of forum participation and to encourage him/her to browse and to post messages.

More precisely an image of a tree appeared in the screen whose characteristics were related to features of participation. The visualization is explained in Table2.

The empirical research was conducted with students of the Information Policy at the Interfaculty Initiative at the University of Tokyo. iTree was accompanying a BBS which has been used for half of the semester (sixth to fifteenth lesson). In the BBS there were conducted Q&A sessions and discussion related to the presentations of special issues made by the students in the class.

The researchers compared 9 students who used iTree with 53 students who did not use it. They reported that the iTree encouraged learners to read forum notes but not to post forum notes (there was no statistical significant difference between the two groups for the latter).

The researchers collected also questionnaires about the Learner's Subjective Evaluations of iTree. Students cared about the growth of the tree and paid more attention to the red nuts and the leaves than the trunk and branches. They have missed the functionality of the sky.

The researchers did not check in details whether the students had the same understanding of the metaphors used in the iTree design as the designers of the software. Moreover it seems that students did not integrate the indicators with a model about how to achieve a better collaboration: The students cared about leaves (read postings) and nuts (replies on postings) but they did not put more postings (especially replies) to entice people to respond to them. In this case it is possible that students cared about the appearance of "their trees" independently from the ongoing learning activity. One can think that they would also pay more attention to features that make the tree more beautiful rather than features that are more closely connected with the learning results. (The researchers do not report whether they tried to establish a correspondence between the two in their design). One can also argue that the same results with respect to participation could be achieved with just a message informing that there have been replies to their postings.

The researchers claim that in future research they intend to change the iTree graphic interface to promote more postings by the students.

**2. Vassileva, J., Cheng, R., Sun, L. & Han, W. (2005). *Designing Mechanisms to Stimulate Contributions in Collaborative Systems for Sharing Course-Related Materials, ITS 2004 Brazil***

The goal of the researchers was again to encourage participation. "Collaboration" among students was considered in a much weaker sense than usual: the researchers wanted students to share resources, be on-line, answer requests.

The basic software for this research was peer to peer software (Comtella) where students shared resources in an asynchronous way without engaging in dialogue or in collaborative problem solving. In such a system it is very important, for keeping high the interest of the users for the system, to maintain a constant stream of new contributions (shared materials).

Comtella was used as part of an undergraduate course "Ethics and IT". The details of the visualization are presented in Table 2.

The researchers deliberately tried to use lessons from social psychology to influence the interaction in Comtella.

In the study 29 students participating in the Ethics and IT course used the Comtella system. The Visualization status and reward for participation was introduced after the sixth week. The researchers compared the students' participation before and after providing feedback.

They found that the number of new articles shared the last four weeks were twice the ones shared the first six weeks. Ratings and comments of articles were increased (it is not mentioned if this was statistically significant)

However

- a) the quality of the shared resources somewhat decreased
- b) users used irrelevant material to keep their high hierarchical level

The researchers used also questionnaires referring to the opinions of the students about the feedback they were getting and found that the students cared about the size of their circle.

In this case there was no control condition to check for the effects of just participation time in the course. However the research gives us some indications that using social psychology means in order to influence students without having gained their acceptance for the process can be a double edged sword. Participants may be influenced towards non participating (by the same subconscious mechanisms) when many other students do not participate (and this becomes clear now by the indicators). They also may try to cheat the system to get higher ratings.

In their future work the researchers intend to make the users do the qualitative work by using rating systems and trying to find ways to avoid pitfalls of such solution due to



invalid ratings (computing reputation, creating sub communities of similar interests, rewarding of quantity and quality in rating). However in no case to they seem to intend to build on changing the classroom culture.

**3. Zumbach, J., Muehlenbrock, M., Jansen, M., Reimann, P. & Hoppe, H.-U. (2002). *Multidimensional Tracking in Virtual Learning Teams. In Gerry Stahl (Ed.), Computer Support for collaborative learning: Foundations for a CSCL community (pp. 650-651). Hillsdale, NJ: Erlbaum.***

The researchers followed McGrath (1991) TIP theory in suggesting three success factors for learning communities:

- a) production function: working on a common task
- b) group well-being: maintaining the communication and interaction among group members
- c) member support: helping the individual member when necessary

Putting special emphasis on factors related to the second function of successful groups. In their own words:

“In our approach we experiment with techniques to a) dynamically elicit emotional and motivational state of the group members and b) to feed this information back to the group by making use of visualization techniques for highlighting trends over time and for pointing out individual deviations from the group average. In other words, we focus on turning individual motivational and emotional states in knowledge that is shared by all group members. We are furthermore interested in how groups make use of such information once it is available to them. Finally, we are interested in the effects of supporting group well-being on the outcomes of the learning or work”

The participants of the study were adhoc groups which worked together for only a number of hours. They were working on EasyDiscussing, an application where the participants work in a shared workspace and drag typed cards from a set of typed cards and drop them at an arbitrary position in the work place. Each group that participated had to solve a problem with many “correct” solutions: The learners had to develop an online screen version of a linear text by chunking linear text into coherent parts, adding or deleting parts, providing adequate headings and develop a navigation structure. The group members spented two hours both in collaborative work and in collecting the necessary information from supportive online resources. Each member of a group was working in a different room.

There were used both experimental and control conditions. In both cases there participated three groups of three people (university students from 21 to 42 years). Every 30 to 40 minutes the participants were asked to fill a 5-point Lickert scale in reaction to the questions “How do you feel?” and “To which degree are you motivated to work on this task?”. However the values for each entry and for each subject were displayed only to the experimental group members using dynamic graph.

The researchers found that providing motivational and emotional feedback did not contribute to significant difference in the disciplinary knowledge gained (assessed by pre and post tests) which was high in both the experimental and the control conditions. Moreover there was no difference in the attitudes towards cooperative learning and in their final emotional state.

There was reported an increase in motivation for the experimental group only. There were also indications of a more equally distributed contribution in the case of experimental groups. A study of the interaction patterns showed indications of more interactive behaviour in the experimental group.

However we notice that this increase in interactive behaviour was not accompanied with higher performance. One is tempted to question whether the use of indicators promotes other changes also in the learning environment that counterbalance the beneficial effects that one would expect for the final solutions from the improved interaction among the members of the group.

The researchers intend (in future work) to increase and refine the number of parameters utilized to assess and visualize group well-being, including socio-metric measures and tracing of the work on the task (design histories).

**4. Zumbach, J., Hillers, A. & Reimann, P. (2003). *Supporting Distributed Problem-Based Learning: The Use of Feedback in Online Learning*. In T. Roberts (Ed.), *Online Collaborative Learning: Theory and Practice* (pp. 86-103). Hershey, PA: Idea.**

Following their previous work, presented above, the researchers provided feedback both for the interactions and for the problem-solving processes.

In this study there participated 33 university students, in groups of three to five members. They participated as part of their work in a problem-based course about instructional design. They were required to design several online courses for a fictitious company. The project had to be completed in two weeks and at the end of each task the groups presented their results to other groups.

The asynchronous collaboration of the participants took place on software built on the Lotus Notes platform. The software was enriched with the capacity of displaying Interaction Indicators that gave visual feedback on a) the participation behavior b) the learner's motivation (through self-ratings as in the previous study) c) the amount of contributions. These data could be presented as dynamical diagrams (interaction histories). Moreover their solutions were rated by tutors and a history of their solution scores could also be provided in a visual form (design histories).

The groups were randomly assigned to one of four treatment conditions: with interaction histories only, with design histories only, with both interactions and design histories and with none of the two.

The researchers found that “Groups that were shown design histories on their workspaces presented significantly better results in knowledge tests, created qualitatively better products in the end, produced more contributions to the task, and expressed a higher degree of reflection concerning their organization and coordination... the presence of interaction histories influenced the members’ emotional attitude towards the curriculum and enhanced their motivation for the task”

The researchers concluded that different kinds of feedback influenced different aspects of group behavior. Feedback in the form of design histories seemed to influence a group’s production function while feedback in the form of interaction histories has its main effect on the group’s well-being function.

In the light of previous research on collaborative learning unassisted by computers this result seems peculiar. It looks as if in an environment providing certain feedback indicators, the interaction climate and the quality of final products can become disengaged.

The researchers point to the infancy of the domain and the importance to have a more mature software support for more efficient study of the influence of various indicators. Following the TIP theoretical scheme about group functioning they propose as direction of research the connection between different feedback provided to the participants and different group functions. They also point the importance of taking into account cognitive load when designing indicators.

**5. Zumbach, J., Schönemann, J., & Reimann, P. (2005). *Analyzing and Supporting Collaboration in Cooperative Computer-Mediated Communication*. In T. Koschmann, D. Suthers, & T. W. Chan (Eds.), *Computer Supported Collaborative Learning 2005: The Next 10 Years!* (pp. 758-767). Mahwah, NJ: Lawrence Erlbaum.**

Building on the previous research presented above, the researchers designed a 2X2 factorial experiment to test the influence of distributed learning resources as well as feedback related to collaboration on outcomes of knowledge acquisition, quality of problem solving, group climate and number of collaborative events in a networked-based cooperative learning scenario (related to depression and anorexia nervosa). Learning objectives included knowledge about cause, diagnosis, development and therapy of depression and anorexia nervosa as well as relations among the two. In this study there participated 40 students from the University of Heidelberg. The participation in the problem solving task lasted 1,5 hours. The learners were working in dyads and had to solve a case following a Problem-Based learning approach.

The collaboration feedback was mediated by assessment done by the experimenter. Using available categorizations of good collaboration sequences, the experimenter would identify such sequences synchronously as the discussion in the chat window was unfolding and send messages “You have successfully cooperated! Keep on” and a counter of collaborative events would rise.

The variation with respect to the distribution of learning resources had to do with giving to each learner access to all the material or access each for one disease (one of them for anorexia nervosa and one for depression).

Before and after the task the students took a test about the subject matter of the task. They also took a post test about the group climate. The researchers also counted the number of collaborative events in all cases as well as assessed the quality of each participant's problem solution.

The researchers found that monitoring students' interaction behavior and providing feedback on collaboration triggers further collaborative behavior and influences problem solving processes leading to significantly better individual problem solutions.

However as far as knowledge acquisition is concerned the picture is more hazy. No enhancement in knowledge acquisition using a common test format was found.

No difference in the final group climate among the different groups was detected.

Due to the human judge in this case there was provided a much more sensitive feedback about the students' collaboration. However as the researchers themselves remark the students were fed back only the number of "exemplary collaboration episodes" but no conceptual information about their collaborative learning behavior (the kind of collaboration that was observed). That is they were not supported towards developing more sophisticated models about their collaboration.

We do not know how important was for students the influence of the knowledge that the experimenter was continually following their exchanges in such a detail as to provide direct feedback. Moreover in everyday language congratulations for collaboration do not have the technical meaning of a scientific definition but usually have also overtones of task achievement. So students may have had the sense that the examiner was following closely the meaning of their contributions as well. Such interpretations from the side of the students could cause a motivation for focused effort that might not exist if the feedback was provided in an automatic way even for non task collaborative interaction (and this was known by the students).

The researchers propose that semantic techniques and statistical text analysis approaches could possibly take the place of the human agent for "more or less well-defined discourse areas and small group sizes".

### **6. Jerman, P. (2004). *Computer Support for Interaction Regulation in Collaborative Problem Solving, PhD Thesis***

We present here only part of this extended work

The researcher did two experiments. In each of the experiments the participants had to collaboratively solve a problem about traffic management. A characteristic of this problem is that students have to wait for some time for the traffic simulation to stabilize before trying to get some conclusions for their further action.

In the first experiment the indicators provided to the students were just mirroring the interaction (participation in the discussion and in problem solving actions) without any explicit normative value feedback by the software to the students depending on the indicators' values. The researcher found that the interaction had not been influenced in significant ways: Dialogue asymmetry was not reduced. Moreover the cooccurrence of task and interaction regulation did not increase. The researcher estimated that the participants did not pay much attention to the indicators and did not have sufficient knowledge about productive collaboration in order to interpret the output of the indicators and regulate their behavior in a fitting way.

“we conclude that for mirroring tools to affect the characteristics of the interaction, a “desired” model of interaction has to be present, either as a part of the subjects' mental model of the interaction, or as an explicit referent represented in the interaction meter.”

In the second experiment students were provided with an indicator that was visually representing the balance between talking and tuning in the traffic control problem. The indicator was calculated dynamically and was presented every 1 minute to the students. The indicator was also showing the “good” region of relation between talking and tuning.

In this case the tool encouraged the participation in dialogue by positively valuing talking over tuning. As a positive side effect of the increased participation in dialogue, subjects produced more plans and more detailed plans that refer to more parameters of the problem. Moreover the subjects participated more equally to the planning. However there was no connection between the use of the indicator and the successful completion of the problem. Plans may be more detailed and result from the contributions of both subjects without leading to a solution.

**7. Mochizuki, T., Kato, H., Hisamatsu, S., Yaegashi, K., Fujitani, S., Nagata, T., Nakahara, J., Nishimori, T. & Suzuki, M. (2005). *Promotion of Self-Assessment for Learners in Online Discussion Using the Visualization Software. CSCL conference Taiwan 2005***

The researchers enriched a Bulletin Board System with a visualization software i-Bee. I-Bee could visualize the relationship between learners and keywords in online messages in real time. It also provided snapshots of past discussions and animations. The keywords of the topic were selected by the teachers.

In this case distance functions need to be calculated between students and keywords and this is done automatically by the software taking into account the frequency of the keywords in the messages of the learners.

The researchers wanted to support their students in their self-assessing of their place in an ongoing discussion and in reflecting about the overall discussion.

Table 1 presents the details of the visualization.

Therefore in this case learners are situated close or far away depending on their relationships with keywords. Moreover “common interest” can be extracted through common orientation to a keyword (flower).

In their empirical research the 9 participants were preservice teachers which were preparing their portfolios based on their internships in junior high schools. The discussion of these portfolios was the subject of an undergraduate course. The participants used a BBS to write down their thoughts on their portfolios and comment on each others’ experience. This happened for 15 to 30 minutes at the beginning and the end of 7 out of 10 classes.

The researchers videotaped two students sitting next to each other and exchanging verbal comments while at the same time they were writing their comments in the BBS. At the same time i-Bee was visualizing the whole discussion.

Based on these data the researchers argue that i-Bee helped students to orient in the discussion by identifying students “close” to them (and therefore “interesting to read their comments”) and by showing whether somebody was left outside the themes that were attracting the interest of the majority.

The researchers do not provide data on how transparent all the aspects of the visualization were.

Although we see that there are changes in the realtime behavior of students ( becoming apparent by creating a situation that approaches a think aloud protocol) we have no data on what are the consequences of these changes. The researchers recognize this as one of their future challenges.

**8. Ogata, H. & Yano, Y. (2004). Knowledge Awareness Map for Computer-Supported Ubiquitous Language-Learning. Proceedings of the 2<sup>nd</sup> IEEE International Workshop on Wireless and Mobile Technologies in Education (WMTE'04).**

In this paper the students were not engaged in collaborative problem solving but in the sharing of relevant information. The focus was second language learning and in particular learning of specific expressions appropriate in certain environments (e.g. a hospital). Participants were using Mobile Devices through which they could communicate. A software (CLUE) was creating a visualization which represented knowledge objects that were significant for the participants (in the precise implementation English expressions that were appropriate for the location) and learners that were “close” to these objects and that could be possible sources of help.

In the specific implementation that the researchers present there participated 3 undergraduate and 3 graduate Japanese University Students interested in learning English. The teacher of the English as a Second Language course had specified 89 English sentences that would be appropriate to use in specific locations in the University campus. The Mobile phone would locate the students at different points in the University campus and present to them the appropriate questions for the place they

were located and in a sequence that fitted the profile that the system was dynamically keeping for each student. (The software has profiles of the students. In order to make the profile of the user the software used both the history of students' actions and the students' own descriptions of their interests.). If the students could not understand the meaning of a question they tried to find in a visualization provided by the software who are the students that they could ask based on a map that CLUE produced. The interest of the possible helpers to the particular location and their level of knowledge were used to visualize the distance from the needed expression while characteristics of their profile influenced the CLUE's decision on whether it would present a student as a possible helper (in the map) or not.

The students were divided in two groups. Those that used CLUE and those that just studied the relevant classroom material. The researchers observed a great difference in learning the selected expressions between the students who participated in CLUE and those who did not. Moreover the students answered a questionnaire about CLUE in which students assess in a very positive CLUE's contribution to their learning. However some thought that it had not been easy to understand its functionality.

The researchers did not test in detail the transparency of their visualizations. Moreover in their design there is a conflation between using CLUE and giving extra time and using new material to learn the particular expressions.

The researchers think that a possible fruitful direction would be to make the whole trip virtual and put the students to move around and do the same kind of interaction in a digital city.

**9. Baker, M.J., Quignard, M., Lund, K., & Sejourne, A. (2003). Computer-Supported Collaborative Learning in the Space of Debate. CSCL conference**

The researchers have created a software (DREW) where participants can jointly construct arguments. Interaction analysis is given in this case in an indirect way: In cases where the software system detects arguments by different people leading to contradictory stances towards particular statements it changes the shapes of the boxes that represent the statements (squeezes them) and therefore creates a signal for the existence of a conflict. Again the knowledge objects mediate the expression of information about interaction. In this case the information has an on/off character (we agree / we disagree).

The researchers carried an experiment with secondary students. In the experimental class comprised by 21 students, the students worked in dyads and used the CHAT and the GRAPH functionality. In the control class comprised by 28 students working in dyads the students used only the CHAT functionality. Although the students improved in the quality of their argumentative texts in both cases there was no difference between the experimental and the control condition.

We are not provided with information about the way in which the squeezing feature (that was expressing disagreement among students) was actually used by them.

**10. Van Joolingen, W. R., De Jong, T., Lazonder, A. W., Savelsbergh, E. R., & Manlove, S. (2005). *Co-Lab: research and development of an online learning environment for collaborative scientific discovery learning. Computers in Human Behavior, 21, 671-688.***

The researchers were interested whether a Process Coordinator tool would be effective for supporting self-regulation of (collaborative) scientific inquiry learning activities of students.

There participated 61 students (19 triads and 2 dyads) 16-18 year old which were split in an experimental and a control group. The students worked for 3 sessions ( approx. 3 hours total) on a Water management module in the Co-Lab learning environment

They worked with the Co-Lab computer-based environment for collaborative learning. Feedback about the interaction was given through The Process Coordinator, module that contains goals and sub goals in order to guide learners through the different stages of the learning process. It contains descriptions of each of the (sub)goals and also hints on ways of reaching those goals. In the Process Coordinator, learners can create their own learning goals, make notes associated to the goals present, and review these notes on a History page. They also can tick off goals they consider completed.

The effectiveness of the Process Coordinator was evaluated by comparing two groups. The experimental group had access to a fully specified version of the tool, which included a hierarchy of goals and subgoals as well as hints which were specific to each step. Students in a control group had access to the Process Coordinator tool which was fully functional but had no content.

The experiment was divided over three sessions. The first session served as a short introduction to the learning environment and to the different tools that would be available in it. The second and third sessions had students working on a collaborative discovery learning task in the Co-Lab environment. Students were seated in a computer lab with group members dispersed throughout the room in order to prevent face-to-face communication. They used the Process Coordinator tool for planning. For communication, they used a chat function (no direct communication took place). The students conducted their own inquiries, without direct support.

In order to assess whether students were planning, monitoring and evaluating during their two sessions the use of the Process Coordinator was used as an indicator. All actions students performed were registered in a log file. The actions performed by students were associated with each of the regulating processes that have been mentioned. Planning was defined by four actions: (1) viewing of specific goals, (2) adding goals or subgoals, (3) viewing hints, and (4) viewing the goal descriptions. Three actions were associated with monitoring activities: (1) adding notes to goals, (2) marking goals complete, and (3) checking the history. Evaluation was assessed from (1) generating the report by clicking the corresponding tab, and (2) writing within the report.

The main results of this study indicated a positive effect for the Process Coordinator tool to support self-regulation of collaborative inquiry learning activities of students, particularly for planning. Students who had access to plans performed increased planning activities. Results were less conclusive for an increase in monitoring activities.



**11. Vizcaino, A. (2002) Can a Simulated Student Detect Problems in Collaborative Learning Environments? Proceedings of ICALTS 2002**

This research is different from the previous ones in that Interaction Analysis Indicators have been computed but they were not available for the students. The system compared their values with an ideal and then acted through a Simulated Student in order to “correct” features of the interaction.

In the study participated forty four students divided into pairs. Each pair was working on HabiPro. HabiPro is a software system specially designed to help students develop good programming habits. Its interface provides different workspaces both for sharing the different solutions of the collaborating students and for talking through chat.

The students were told that three students participated in each group but in reality the third student was a Simulated Student.

Of interest to this deliverable was the Simulated Student’s actions of detecting passive students based on a combination of criteria (number of contributions, number of words per contribution, comparison of the individual with the group performance etc) and of detecting off-topic conversation (by checking keywords). The researchers claim that the SS detected and intervened successfully in all cases that a passive student appeared. It intervened unnecessary only once. It intervened with messages like “Ann, you are very quiet. What do you propose” or “What do you think about my proposal Ann?” or “Ann, you aren’t joining in much. Are you tired?” It also detected 12 out of 14 off topic conversations and successfully intervened. In one case it misjudged and on topic conversation as off topic. In this case the SS intervened with comments like “I think the solution is 13, don’t you?” or “I don’t like football. Let’s finish this exercise”.

**12. Petrou, A.& Dimitracopoulou, A. (2003) “Is synchronous computer mediated collaborative problem-solving ‘justified’ only when by distance? Teachers’ points of views and interventions with co-located groups, during everyday class activities”, Proc. Of CSCS-2003, Bergen, June 2003, pp. 369-377, Kluwer.**

The researchers were interested in the following research questions:

1) How valuable synchronous computer mediated collaborative problem solving in real school context, with collocated students, in every day practice, appear to schoolteachers?

2) What tools (support) do teachers need in order to support students and apply on-line or/and off-line students’ diagnosis?

In the study there participated 2 teachers and 10 sixteen year old students. The subject was a Computers’ Programming Lesson and worked for 4 weeks ( 2hours per week) using Windows Netmeeting and Netsupport School

The participants were two teachers (Teacher1 and Teacher2), ten sixteen-year old students, from two different classes (five from each class). Neither teacher had previous experience with computer supported collaborative learning, but Teacher2 is a

researcher and has worked on improving teaching through computer use. The teachers were not provided any initial instruction on collaborative learning and best practices.

*Teachers' interventions* were studied according to the "moment of time" that they have taken place:

- (1) *On-line interventions*: teacher's interventions during the lesson while they observe students' interactions (dialogues and actions at the common workspace).
- (2) *Off-line interventions*: teacher's interventions, during the next course session, after studying a unified file of data provided to them by the researcher.

Usually, the teachers' interventions are studied, by assuming the intention of teachers messages or verbal expressions, attributing 'functional roles' or analyzing "question types and statement types" that correspond to 'how teachers intervene' and lead to the discussion on the quality of teachers interventions, their strategies, and their approach. This kind of analysis seems to distinguish teachers' interventions from students' interactions, and often take place independently.

After the experimental sessions, an interview took place with each one separately.

Each teacher had five students (one group of two and one group of three). The teacher placed students into mixed ability groups. The members of each group worked on their own computers, which were not located in the immediate vicinity of the class. Before starting, the students had a short lesson (20 minutes) on how to use NetMeeting.

Students worked on two activities (simple problem solving) from the lesson *Computers' Programming*, during four instructive hours (4 \* 45 minutes) each class. The activities were not designed for the purpose of the study. They were chosen by the teacher, the students would do these activities anyway. For each activity, one common program (written in Pascal) was required from each team, for example "*write a Pascal program that prints minimum, maximum and average after reading the marks of your classmates*". So, the shared workspace was the environment of Turbo Pascal. At the first activity, it was additionally asked from students to answer the question: "*can you find how many students were above the average without using arrays?*" So, in this case, the final product was a collectively written text and the shared workspace was a Word document.

There was available a variety of indicators: Transcripts from (a) chat history between students and between students and teacher, (b) data from video\* of the actions within the shared workspaces and the teacher's screen and (c) camera recording (spoken dialogue between teacher and students) were linked and merged. Thus, a single transcription file was produced, respecting the chronological order of events, containing the teacher's interventions (verbal and/or written) as well as students' dialogues and actions. This unified file served as the base for analysis, for each team

The analysis showed that computer supported collaborative learning provides the teacher with some new opportunities, in spite of certain difficulties (such as time consumption). This is so because learners interact through messages, and this information is available to the teacher as a resource that can be used to assess the

learning that has taken place. Additionally, a teacher can monitor the actions at the shared workspace during problem-solving. Viewing the details of a problem-solving interaction between students could elucidate students' puzzling behavior. Besides, making the learning process of a group explicit, the teacher can be aware of the students weak and strong points and thus be able to intervene and monitor the group more effectively using different strategies according to the situation. Diagnosis is a really hard activity for teachers, and if they have the opportunity to apply it, at least to a certain degree, we consider that it is significant both for teaching and learning.

The need for providing teachers with tools that analyzes students' activity (both on content and collaboration) and presenting their actions and dialogues in a form that facilitate teachers' understanding, was apparent from our research. More specifically: (a) during synchronous collaborative activities, (on the fly), teachers need to estimate at a glance the evolution of the collaboration in order to intervene accordingly. (b) A posteriori, besides quantitative data concerning learners' participation, a detailed registration of the collaboration in terms of dialogues and actions at the shared workspace in a chronological order is preferable, in order to assess the learning that has taken place and reflect on their own strategies as well.

**13. Petrou, A. Fessakis, A., Mitsoullis, C., Dimitracopoulou A., (2004). *Tools for Interaction Analysis during collaborative problem solving : Uses from Teachers in real school conditions. ICTs in education Conference. Athens, 29 September -3 October 2004.***

Empirical evaluation of the available interactions' analysis tools, that were designed and implemented based on the results of the pre-research

In the research, four teachers were participated, and the students of two classes of K(9) students and two other classes of K(10) students, from three different schools. The students worked on open problems using MODELLINGSPACE. The activities lasted 8 weeks (4 hours per week).

Data (messages and actions at the shared workspace) from log files, teacher's interventions, during the next course session, after studying data from the tools provided to them by the researcher, students & teacher questionnaires, individual interviews with each teacher at the end of each session, were analyzed.

There were available three indicators:

- Collaborative Activity Function (CAF): Teachers could use CAF tool on line in order to estimate: the total group activity, the contribution of each agent, as well as the quality of the interaction according to the communication channel used.
- PlayBack: allows the user to see the whole interaction process like a video tape along with some more possibilities
- Collaboration Progress Reproduction Tool (COPRET):it provided chat history between students and between students and teachers (data from log file), information about key's possession (data from log file), snapshots of the shared

workspace after an action like insertion, modification or deletion occurred (using log file the researcher localize the time points that such action occurred and using Playback Tool he captured the corresponding snapshots of the shared workspace).

Each teacher, beyond the whole class, have supervised and/or guided on-line a specific group of two collaborating students. Neither teacher had any previous experience with computer supported collaborative learning. The teachers were not provided any initial instructions on collaborative learning and best practices. Teachers placed students into mixed ability groups. The members of each on-line supervised group (one teacher and two students) worked on their own computers, which were not located in the immediate vicinity of the class.

Students worked on series of learning activities for 8 sessions of 45 minutes (maximum) available for the full set of learning activities implementation. Students had to solve four open problems (e.g. pricing policies of phone companies, irrigating horses) creating models (finally corresponding to the algebraic relation  $y=ax+b$ ) of the underlying situations, and using them in order to solve the problems.

The available tools provided teachers with some new opportunities since they can have quantitative and qualitative information about collaboration, like the degree of groups' collaborative activity, or each participant's dialogues and actions, including their own ones. As a result, teachers were able to diagnose collaboration quality or cognitive problems and misconceptions and intervene accordingly on the fly or a posteriori. The 'on the fly' intervention is very important since up to now, teachers' interventions resulted from collaboration's snapshots estimation or after students' request. Additionally, a posteriori interventions, resulting from studying each participants' dialogues and actions is very important, since (a) teachers can reflect on their own interventions and self regulate their teaching strategies, (b) misconceptions are more likely to be "changed" if teacher has identified them and then apply appropriate feedback and post-summarization strategies to address them, after the problem solving phase has ended.

**14. Towards effective network supported collaborative learning GSIC Group, Univ. of Valladolid.** *The case study is "in progress" and the results have not yet been published. It is part of a project under the EU e-learning program called TELL (Towards effective network supported collaborative learning) (EAC/61/03/GR009)*

The main research goals were to:

- a) Study the collaboration processes and structures among the participants, by means of the analysis of the sharing of information in the workspace.
- b) Study the teachers' and students' roles that are detected during the learning process.

There participated 26 University students who worked for 11 weeks ( 4 hours per week) on projects that related to ICT used in education. The students used Synergeia and WebQuest.

This study was carried out using social network analysis (SNA) supported by an IA tool called SAMSA. The input for this were the log files provided by the CSCL tool (Synergeia).

The indicators provided by SAMSA were network centralization, network density, and actors' centrality. We also used the visualization of sociograms to detect the evolution of participation and the evolution of roles within the group.

Students had to create a Webquest, that could be eventually used in a real school, and design the ICT resources that would support such a didactic unit. The teachers of a primary school participated in the case study by providing specifications and evaluation of the partial results of the students. The learning environment was a blended one, where normal face-to-face activities are interleaved with technology-supported face-to-face or distance activities.

SAMSA has been used to identify students' and teachers' roles. Students with high degree levels were regarded as potential coordinators. The ethnographic data confirmed that these potential coordinators had been really the leaders in their groups, and that this was coincident with those members of the groups that had a better expertise in the use of computers. Regarding the teachers, social network analysis reflected a shift on the teacher functional roles during the course. The indexes and the sociograms show how the teacher has a prominent participation during the first phase of the process, when the activity starts, and the teacher played the role of the mediator. Later on, the teacher's role becomes that of an observer, reflected by the fact that his activity consisted only on reading the groups' assignments and not having any other interaction with the students (mediated by the CSCL tool).

Table A: Research Methods and Results related to IA tools effects to real users

Research	Experimental Conditions	Methodology	Concept of Indicator	How end-users used the available information	Remarks and further requirements from end-users
<a href="#">Nakahara, Kazaru, Shinichi, Yamauchi, (2005).</a>	Students of the Information Policy – University of Tokyo, Bulletin Board System – iTree, half of the semester.	Experimental and Control group, Questionnaires of learners’ subjective evaluations of iTree were analyzed.	Level of forum participation.	The students cared about the size of the tree (indicator). Read postings and replies on postings but they did not put more postings (especially replies) to entice people to respond to them.	
<a href="#">Vassileva, Cheng, Sun, &amp; Han, (2005).</a>	Comtella, Undergraduate Students - course “Ethics and IT”, ten weeks.	The visualization of status and reward for participation was introduced after the six initial weeks of the course and for four weeks, Students’ participation (share resources, be on-line, answer requests) and questionnaires referring to students’ opinion about the feedback they were getting.	Level of participation.	Students cared about the size of the circle (indicator). This means larger number of shared files.	
<a href="#">Zumbach, Muehlenbrock, Jansen, Reimann, &amp; Hoppe, (2002).</a>	EasyDiscussing (a shared workspace to solve an open problem), University students which worked together for only two hours. Each member was working in a different room.	Experimental and control conditions. Disciplinary knowledge was assessed by pre and post tests, interaction patterns were also analyzed in order to check interactive behavior.	Dynamically elicit emotional and motivational state of the group members by turning individual motivational and emotional states (through self-ratings) in knowledge that is shared by all group members.	Students increased interactive behavior which was not accompanied with higher performance.	
<a href="#">Zumbach, Hillers,</a>	University students worked with	Groups were randomly	Interactions’ histories	Feedback in the form of	

& Reimann, (2003).	Lotus Notes platform - design online courses for a fictitious company about instructional design, for two weeks.	assigned with interaction histories only, with design histories only, with both of them, with none of the two. Interactions were analyzed, knowledge tests were performed and final products were assessed.	presenting participants' behavior and amount of contributions, learner's motivation (through self-ratings as in the previous study).	design histories seemed to influence a group's production function while feedback in the form of interaction histories has its main effect on the group's well-being function.	
Zumbach, Schönemann, & Reimann, (2005).	University students chatting on learning scenario related to depression and anorexia nervosa for 1,5 hours.	Students were working in dyads. Interactions during collaboration were assessed by the experimenter, pre and post test on subject matter of the task were conducted, post test about the group climate as well as assessment of each participant's problem solution.	Immediate collaboration assessment (done by the experimenter who was monitoring the collaboration)	Students increase collaborative behaviour and problem solving processes were influenced leading to significantly better individual problem solutions.	
Jerman, (2004).	Secondary school students were working with simulation of traffic management in laboratories.	Experimental and control groups. Interactions were analyzed as far as dialogue and actions at the shared workspace are concerned.	Level of participation in the discussion and in problem solving actions (with or without normative assessment).	With normative information students' participation in dialogue was encouraged by positively valuing talking over tuning. There was no connection between the use of the indicator and the successful completion of the problem.	
Mochizuki, Kato, Hisamatsu, Yaegashi, Fujitani, Nagata, Nakahara, Nishimori, & Suzuki (2005).	Preservice teachers which were preparing their portfolios based on their internships in junior high school used Bulletin Board System with a visualization software i-Bee. This happened for 15 to 30 minutes at the beginning	The researchers videotaped two students sitting next to each other and exchanging verbal comments while at the same time they were writing their comments in the BBS. Written messages were	Visualize the relationship between learners and keywords in online messages in real time.	i-Bee helped students to orient in the discussion by identifying students "close" to them (and therefore "interesting to read their comments") and by showing whether	

	and the end of 7 out of 10 classes.	analyzed.		somebody was left outside the themes that were attracting the interest of the majority.	
Ogata & Yano (2004)	Undergraduate and graduate Japanese students in an English as a second language course, using Mobile Devices and CLUE software.	The students were divided in two groups. Those that used CLUE and those that just studied the relevant classroom material. Knowledge assessment was contacted and students answered a questionnaire about CLUE.	Represent knowledge objects that were significant for the participants (in the precise implementation English expressions that were appropriate for the location) and learners that were “close” to these objects and that could be possible sources of help.		
Baker, Quignard, Lund, & Sejourne (2003)	Secondary school students worked with DREW where participants can jointly construct arguments.	Experimental and control groups. Argumentative texts were analyzed.	Visualization of conflicts in argumentation.	We are not provided with information about the way in which the squeezing feature (that was expressing disagreement among students) was actually used by them.	
Van Joolingen, W.R., De Jong, T., Lazonder, A.W., Savelsbergh, E.R. & Manlove, S. (2005)	Secondary School students ( age 16-18) worked in the Co-Lab computer-based environment for collaborative learning. 3 sessions, approx. 3 hours total	Students in a control group had access to the Process Coordinator tool which was fully functional but had no content. The experimental group had access to a fully specified version of the tool, which included a hierarchy of goals and subgoals as well as hints which were specific to each step.	Visualization of shared planning	The Process Coordinator was used during collaboration. Students could use the feedback about the planning of an experimental process to improve on it.	



Vizcaino, A. (2005)	Students worked in a computer class with HabiPro. An Artificial Intelligence software was guiding a simulated student.	Two pairs. One with a Simulated Student and one without	Detects passive students based on a combination of criteria (number of contributions, number of words per contribution, comparison of the individual with the group performance etc) and of detecting off-topic conversation (by checking keywords).	Students responded to the suggestions and comments created by the Simulated Student	
Petrou & Dimitracopoulou (2003)	Secondary students and teachers using Windows Netmeeting and Netsupport School, in a real school context, in order to solve activities (simple problem solving).	Teachers and group members were collocated in the same classroom. Teachers' interventions were analyzed.	Details from participants' dialogues and actions.	Assess the learning that has taken place.	(a) During synchronous collaborative activities, (on the fly), teachers need to estimate at a glance the evolution of the collaboration in order to intervene accordingly. (b) A posteriori, besides quantitative data concerning learners' participation, a detailed registration of the collaboration in terms of dialogues and actions at the shared workspace in a chronological order is preferable, in order to assess the learning that has taken place and reflect on their own strategies as well.

<p>Petrou, Fessakis, Mitsoulis, Dimitrakopoulou (2004)</p>	<p>Secondary students and teachers using MODELLINGSPACE for solving open modeling problems.</p>	<p>Teachers and group members were collocated in the same classroom. Dialogues and actions at the shared workspace were analyzed, as well as off-line teachers' interventions and questionnaires concerning teachers' opinion about the available indicators and tools.</p>	<p>1)Collaborative action – during the collaboration (Fesakis et al., 2004). 2)Level of participation (for messages and actions) – after the collaboration. 3)Details from participants' dialogues and actions ) – after the collaboration.</p>	<p>Teachers were able to diagnose collaboration quality or cognitive problems and misconceptions and intervene accordingly on the fly or a posteriori. Additionally, to reflect on their own interventions and self regulate their teaching strategies.</p>	
	<p>University students and a teacher worked with SYNERGEIA for eleven weeks, four hours per week (in two-hour sessions).</p>	<p>Messages and actions were analyzed.</p>	<p>Visualization of social network analysis of data from different sources.</p>	<p>Compare inter-group and intra-group interactions, detect and analyse the different behaviours of the students.</p>	

Table B: Research Results related to IA tools effects, and their visualisations featuresqaZA

Research	Goal-Aim of the research	Vizualization	Results
<a href="#">Nakahara, Kazaru, Shinichi, Yamauchi, (2005).</a>	To increase student participation	An image of a tree appeared in the screen whose characteristics were related to features of participation. Thicker trunk and more branches (More posts by the student) More and greener leaves (Posts by the student are read by more people) Leaves fall (After a certain time of not been read any more) Red nuts (Each red nut corresponds to a reply by another student) Bluer sky (The ratio of replies to posts increases)	iTree encouraged learners to read forum notes but not to post forum notes Students cared about the growth of the tree but ignored some aspects of the wallpaper appearance (colour of sky)
<a href="#">Vassileva, Cheng, Sun, &amp; Han, (2005).</a>	To encourage participation.	Filled Circle or Empty Circle (On-line or Off-line participant) Bigger size of circle: 4 sizes (Larger number of shared files) Hierarchical level: bronze, silver, gold (Higher level has better search functionality and better visibility) Visualization by hierarchical level (Status with respect to other members) Warning message about danger of falling level(lessened contributions to the system , impeding loss of status) Window showing the level of the contribution of the user with respect to several factors in comparison with the top contributor for the week for each factor (Appears after the warning sign. It motivates the participant to take corrective action.)	The number of new articles shared the last four weeks were twice the ones shared the first six weeks. Ratings and comments of articles were increased The students cared about aspects of the visualization (size of circle) The quality of the shared resources somewhat decreased Users used irrelevant material to keep their high hierarchical level.
<a href="#">Zumbach, Muehlenbrock, Jansen, Reimann,</a>	Does motivational and emotional feedback influence learning, group motivation, group climate?	Highlighting trends over time and pointing out individual deviations from the group average with a dynamic graph.	Providing motivational and emotional feedback did not contribute to significant difference in the disciplinary knowledge gained (high in both the experimental and the

& Hoppe, (2002).			control conditions) No difference in the attitudes towards cooperative learning and in their final emotional state. Only for the experimental group there was <ul style="list-style-type: none"> <li>• Increase in motivation</li> <li>• more equally distributed contributions</li> <li>• more interactive behaviour</li> </ul>
Zumbach, Hillers, & Reimann, (2003).	Does motivational ,emotional feedback and feedback for the problem-solving process influence learning, group motivation, group climate?	Dynamical diagrams (interaction histories). Their solutions were rated by tutors and a history of their solution scores could also be provided in a visual form (design histories)	Groups that were shown design histories on their workspaces presented significantly better results in knowledge tests, created qualitatively better products in the end, produced more contributions to the task, and expressed a higher degree of reflection concerning their organization and coordination.. The presence of interaction histories influenced the members' emotional attitude towards the curriculum and enhanced their motivation for the task Different kinds of feedback influenced different aspects of group behavior. Feedback in the form of design histories seemed to influence a group's production function while feedback in the form of interaction histories has its main effect on the group's well-being function.
Zumbach, Schönemann, & Reimann, (2005).	Test the influence of distributed learning resources as well as feedback related to collaboration on outcomes of knowledge acquisition, quality of problem solving, group climate and number of collaborative events in a networked-based cooperative learning scenario.	The collaboration feedback was mediated by assessment done by the experimenter. Using available categorizations of good collaboration sequences, the experimenter would identify such sequences synchronously as the discussion in the chat window was unfolding and send messages "You have successfully cooperated! Keep on" and a counter of collaborative events would rise.	The researchers found that monitoring students' interaction behavior and providing feedback on collaboration triggers further collaborative behavior and influences problem solving processes leading to significantly better individual problem solutions. However as far as knowledge acquisition is concerned the picture is more hazy. No enhancement in knowledge acquisition using a common test format was found. No difference in the final group climate among the different groups was detected.
Jerman, (2004).	.Does it matter wether the IA feedback provided to the users contains normative information?	Two kinds of indicators used in two different experiments 1) Mirroring the interaction (participation in the discussion and in problem solving actions) without	Without normative information the interaction had not been influenced in significant ways: Dialogue asymmetry was not reduced. Moreover the cooccurrence of task and interaction regulation did not increase.

		<p>any explicit normative value feedback.</p> <p>2) Visually representing the balance between talking and tuning in the traffic control problem. The indicator was calculated dynamically and was presented every 1 minute to the students. The indicator was also showing the “good” region of relation between talking and tuning.</p>	<p>With normative information, the participation in dialogue was encouraged by positively valuing talking over tuning. As a positive side effect of the increased participation in dialogue, subjects produced more plans and more detailed plans that refer to more parameters of the problem. Moreover the subjects participated more equally to the planning. However there was no connection between the use of the indicator and the successful completion of the problem. Plans may be more detailed and result from the contributions of both subjects without leading to a solution.</p>
<p>Mochizuki, Kato, Hisamatsu, Yaegashi, Fujitani, Nagata, Nakahara, Nishimori, &amp; Suzuki (2005).</p>	<p>Support their students in their self-assessing of their place in an ongoing discussion and in reflecting about the overall discussion</p>	<p>Bee (Learner) Flower (Keyword) Distance between flower and learner (The more a learner uses a keyword the shorter this distance becomes) Direction of the bee (Towards the keyword that is more often used recently) Activity of the bee (Recent activity of the learner compared to his/hers overall activity) Level of blossoming of the flower (Popularity of the keyword compared to the popularity of other keywords)</p>	<p>i-Bee helped students to orient in the discussion by identifying students “close” to them (and therefore “interesting to read their comments”) and by showing whether somebody was left outside the themes that were attracting the interest of the majority. No data on how transparent all the aspects of the visualization were</p>
<p>Ogata &amp; Yano (2004)</p>	<p>To learn specific expressions appropriate in certain environments (e.g. a hospital).</p>	<p>The Mobile phone would locate the students at different points in the University campus and present to them the appropriate questions for the place they were located and in a sequence that fitted the profile that the system was dynamically keeping for each student. (The software has profiles of the students. In order to make the profile of the user the software used both the history of students’ actions and the students’ own descriptions of their interests.). If the students could not understand the meaning of a question they tried to find in a visualization provided by the software who are the students that they could ask based on a map that CLUE produced. The interest</p>	<p>There was great difference in learning the selected expressions between the students who participated in CLUE and those who did not. Students assess in a very positively CLUE’s contribution to their learning. Some thought that it had not been easy to understand its functionality</p>

		of the possible helpers to the particular location and their level of knowledge were used to visualize the distance from the needed expression while characteristics of their profile influenced the CLUE's decision on whether it would present a student as a possible helper (in the map) or not	
Baker, Quignard, Lund, & Sejourne (2003)	Can visualization of argumentation and of conflicts in arguments lead to improved arguments?	In cases where the software system detects arguments by different people leading to contradictory stances towards particular statements it changes the shapes of the boxes that represent the statements (squeezes them) and therefore creates a signal for the existence of a conflict.	The students improved in the quality of their argumentative texts in both cases and there was no difference between the experimental and the control condition.
Van Joolingen, W.R., De Jong, T., Lazonder, A.W., Savelsbergh, E.R. & Manlove, S. (2005)	Search for increased instances of planning, monitoring of the learning task, and evaluation, task attainment and better modeling quality for the students who used the Process Coordinator tool	The Process Coordinator contains goals and sub goals in order to guide learners through the different stages of the learning process. It contains descriptions of each of the (sub)goals and also hints on ways of reaching those goals. In the Process Coordinator, learners can create their own learning goals, make notes associated to the goals present, and review these notes on a History page. They also can tick off goals they consider completed. A chat function offered additional communication	Process Coordinator tool supports self-regulation of collaborative inquiry learning activities of students, particularly for planning. Students who had access to plans performed increased planning activities. Results were less conclusive for an increase in monitoring activities.
Vizcaino, A. (2005)	Would an AI indicator intervene successfully in changing the social dynamics of an interacting group?	Interaction Analysis Indicators have been computed but they were not available for the students. The system compared their values with an ideal and then acted through a Simulated Student in order to "correct" features of the interaction. The students saw the action of the SS.	SS detected and intervened successfully in all cases that a passive student appeared. It intervened unnecessary only once. It intervened with messages like "Ann, you are very quiet. What do you propose?" or "What do you think about my proposal Ann?" or "Ann, you aren't joining in much. Are you tired?" It also detected 12 out of 14 off topic conversations and successfully intervened. In one case it misjudged and on topic conversation as off topic. In this case the SS intervened with comments like "I think the solution is 13, don't you?" or "I don't like football. Let's finish this exercise".

<p>Petrou &amp; Dimitracopoulou (2003)</p>	<p>1) How valuable synchronous computer mediated collaborative problem solving in real school context, with collocated students, in every day practice, appear to schoolteachers? 2) What tools (support) do teachers need in order to support students and apply on-line or/and off-line students' diagnosis?</p>	<p>Transcripts from (a) chat history between students and between students and teacher, (b) data from video* of the actions within the shared workspaces and the teacher's screen and (c) camera recording (spoken dialogue between teacher and students) were linked and merged. Thus, a single transcription file was produced, respecting the chronological order of events, containing the teacher's interventions (verbal and/or written) as well as students' dialogues and actions.</p>	<p>Using the first tool, the researcher found that the interaction had not been influenced in significant ways: Dialogue asymmetry was not reduced. Moreover the cooccurrence of task and interaction regulation did not increase. Using the second tool, the participation in dialogue was encouraged by positively valuing talking over tuning. As a positive side effect of the increased participation in dialogue, subjects produced more plans and more detailed plans that refer to more parameters of the problem. Moreover the subjects participated more equally to the planning. However there was no connection between the use of the indicator and the successful completion of the problem. Plans may be more detailed and result from the contributions of both subjects without leading to a solution.</p>
<p>Petrou, Fessakis, Mitsoulis, Dimitrakopoulou (2004)</p>	<p>Empirical evaluation of the available interactions' analysis tools, that were designed and implemented based on the results of the pre-research</p>	<p>1) Time diagrams for each agent and/or communication channel separately. 2) Number of messages and actions per participant. 3) Transcripts from (a) chat history between students and between students and teacher, (b) data from video* of the actions within the shared workspaces and the teacher's screen and (c) camera recording (spoken dialogue between teacher and students) were linked and merged. Thus, a single transcription file was produced, respecting the chronological order of events, containing the teacher's interventions (verbal and/or written) as well as students' dialogues and actions.</p>	<p>The available tools provided teachers with some new opportunities since they can have quantitative and qualitative information about collaboration, like the degree of groups' collaborative activity, or each participant's dialogues and actions, including their own ones. As a result, teachers were able to diagnose collaboration quality or cognitive problems and misconceptions and intervene accordingly on the fly or a posteriori. The 'on the fly' intervention is very important since up to now, teachers' interventions resulted from collaboration's snapshots estimation or after students' request. Additionally, a posteriori interventions, resulting from studying each participants' dialogues and actions is very important, since (a) teachers can reflect on their own interventions and self regulate their teaching strategies, (b) misconceptions are more likely to be "changed" if teacher has identified them and then apply appropriate feedback and post-summarization strategies to address them, after the problem</p>

	<p>Can the indicators assist the teacher to understand how the students interacted throughout the shared workspace, and to discover the structure of the groups that emerges from the actual interactions among the members of the classroom.</p>	<p>The indicators are network centralization, network density, and actors' centrality. We also used the visualization of sociograms to detect the evolution of participation and the evolution of roles within the group.</p>	<p>solving phase has ended.</p> <p>The teacher could extract from the data some valuable results:                  Comparison of inter-group and intra-group interactions</p> <p>Interaction analysis supported by SAMSA has been useful to detect and analyse the different behaviours of the students regarding these collaboration structures, and has supported the distinction between groups with different levels of collaboration "intensity":</p> <p>SAMSA has been used to identify students' and teachers' roles.</p>
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### **III.3. Discussion**

#### **III.3.1. The Phenomenological perspective**

Users' experience of using IA indicators in the learning environment is found in the literature in three forms:

- a. users reported whether they liked using the IA indicators (Nakahara et al. 2005, Ogata et al. 2004)
- b. users reported their feelings towards the group and/or their motivation to participate when IA indicators were used ( Zumbach et. al. 2002, Zumbach et al 2003, Zumbach et al 2005)
- c. users (teachers only) provided feedback to contribute in a process of joint design of new indicators ( Petrou et al 2003, Πέτρου 2004 )

In the first two cases the rationale behind the feedback did not include the option of changing the IA indicators according to the users' comments. This is an indication that the researchers value their own knowledge much higher than the knowledge available by the teachers or the students about the learning environments in the classrooms. Both teachers and students are not treated as intentional learners who have a say on the process of their learning.

In the last case indicators were designed according to end-users needs, as they revealed during a pre-research. Indicators that were used during synchronous collaborative activities (on the fly), as well as indicators that were used a posteriori.

As a whole this perspective is represented in a very weak way among the reviewed research.

#### **III.3.2. The Interactionist perspective**

This perspective is well represented among the reviewed research. All of the research about IA indicators addressed to teachers and 6 research papers with IA indicators addressed to students (Nakahara et al 2005, Vassileva et al. 2005, Zumbach et. al. 2002, Zumbach et al 2003, Zumbach et al 2005, Vizcaino 2002) stated goals related to the interactionist perspective.

In the case of student directed indicators researchers were mostly interested in a rough assessment of the level of “participation”. Only in one case (Mochizuki et al. 2005) has there been a more detailed examination of the interactions among the students videotaping and analysing their interactions in parallel to their problem-solving work. In one more case (Vizcaino 2002) the researchers intervened through influencing the interaction but we only get to know that this specific approach worked and not how lessons could be transferred in other cases. The evidence provided by the research leads us to believe that appropriate Interaction Analysis indicators can indeed influence the level of interactivity among the students and their participation in the activities. However the connotations of this success may be different from the ones in a traditional collaborative learning environment, as we will argue in the next section.

As a whole, although this perspective is well represented, the methodologies used to study the interaction are not the most fitting. We are not provided with detailed analysis of how students interacted with the other students with or through the indicators. Moreover since the students were not asked about their experience of working with the indicators we are left only with coarse grained results about participation.

In the case of indicators addressed to teachers, Petrou et al 2003 and Πέτρου 2004 report positive effects on teachers’ strategies. Messages and actions at the shared workspace are available to teachers as a resource that can be used to assess the learning that has taken place. Viewing the details of interactions, could elucidate students’ puzzling behavior. Making the learning process of a group explicit, the teacher can be aware of the students weak and strong points and thus be able to intervene and monitor the group more effectively, using different strategies according to the situation. The available indicators provided teachers with the ability to diagnose cognitive difficulties and misconceptions, assess collaboration quality and diagnose discrepancies in collaboration.

In the Valadolid research we are informed about how the teacher could use the data to analyse the interaction that had taken place during the course that preceded. However we have no detailed data about how IA indicator results entered in the pedagogical problem-solving of the teacher or about how these results influence teacher-student discussions about the course of the lessons.

### III.3.3. The Cognitivist perspective

This perspective is well represented among the reviewed research since it interested nearly all of the involved researchers.

However some of the results are surprising. Although it is well documented in non-computer collaborative learning that collaboration and the building of engagement in the task are correlated with increased academic performance three papers (Zumbach et. al. 2002, Zumbach et al 2003, Zumbach et al 2005) reported a dissociation between motivation towards the task and affect towards the group on the one hand and academic performance on the other. This result agrees with reports that increase in participation is not correlated with increase in the quality of the work through which one participates (Nakahara et al 2005, Vassileva et al. 2005).

We think that these results point to a significant issue related to the degree of control that students have on the problem solving process. This control depends on their understanding of issues related to the dynamics of a working group and their ability to assimilate information provided by the IA indicators with models about collaborative work in groups that are already available for the students and therefore regulate the collaborative problem solving process.

In cases where the IA indicators give results that can be interpreted in the context as “rules of order” that make a lot of sense even for the layman (e.g. “don’t speak all the time, leave other people talk as well”, “don’t rush to make changes, think and discuss about what you need to do”) as in research 6, there are many positive results from a cognitivist point of view. However when relying in unreflected influences provided by social psychology mechanisms the results may be contrary to the expected ( e.g. Vassileva et al 2005) leading students to imitate unwanted but popular behavior in the classroom. Finally when students do not have the models to reason about their IA indicators results and about how cognitive and interactivity goals interrelate, the result can be the reported dissociation between degree of interactivity and cognitive gains: increasing participation does not necessarily need to increased task quality.

In the work related to IA indicators addressed to students the availability of Interaction Analysis indicators was not combined with lessons designed to build models about the interaction and influencing the culture of the classroom.. The consequences of the absence of such support is recognized in the case of at least one researcher “Limitations of mirroring

tools' efficiency might come from two sources. First, it is not guaranteed that our subjects build and maintain a model of their interaction and second, the model they hold might not correspond to the model of productive interaction that we promote as designers of the system... For metacognitive tools to be beneficial, subjects have to correctly interpret the normative information that is displayed to them" (Jerman 2004). However in the cases where researchers state their future plans the emphasis is in changes in technology. There is no focus on the design of the whole learning environment and changes in other aspects of it that should accompany the introduction of IA indicators.

Some other approaches that gave interesting results from the cognitivist point of view were Nakahara et al 2005, Mochizuki et al 2005, Ogata et al 2004 where the interaction was implicitly visualized through the mediation of knowledge objects and Van Joolingen et al. 2005 where the communication environment was extremely structured through preset plans. Although these results are tentative they support a view that perceives conscious regulation of the deeper aspects of an interaction a very formidable challenge for students. Providing additional scaffolding through other means (knowledge objects and plans) that implicitly provide messages about the interaction may be easier to handle for students.

In the case of IA indicators addressed to teachers, the first two studies report that the available indicators enable teachers to reflect on the available interaction analysis data, in order to be aware of their own interventions, identify the effects that might cause to the students' reasoning and behavior, and therefore do metacognitive thoughts, and self-regulate their strategies during next sessions.

There are some important indicator format issues related to this perspective:

A first important issue is the transparency of the visualizations of the interaction indicators. The researchers often do not assess in detail the relation between the correspondences that they have designed and the way students understand the various features of the visualization. However remarks in Nakahara et al 2005, Vassileva et al 2005, Mochizuki et al 2005, Ogata et al 2004, Baker et al 2003, indicate that the transparency of the visualizations (the correspondence between designer intent and student interpretation) should be carefully studied and guidelines be provided by the research.

A second issue refers to whether interaction feedback is given directly or in a more oblique way. In most of the research reviewed the IA indicators referred directly and explicitly to characteristics of the interaction. However in Nakahara et al 2005, Mochizuki et al 2005 and Ogata et al 2004, knowledge objects were used as intermediaries so that student interaction can be perceived by the participants in an indirect way. Finally in Vizcaino 2002 the software intervenes in the dynamics of the interaction through an artificial intelligence agent who affects the interaction and at the same time works as a model for the other participants . The evidence (which is not conclusive) indicates that this direction of research which is intermediate between not providing interaction information at all and providing explicit information through clear interaction analysis indicators may be fruitful.

The other important issue that emerge from the review is the degree of constraining guidance that users get through the indicators. In Jerman 2004 this guidance is effected through indicators that specify certain patens of interaction as preferable than others (using the social status that the author of the software has over its users). In Van Joolingen et al 2005 users were constrained in a narrow path that was expressing the normative stance of the authors of the software about the experimental method. In both cases it is the constrained situation that gives evidence of more valuable results for the users. However, as noted above, in all these cases students were not supported by other aspects of the broader learning environment towards becoming more apt in the use of concepts that help comprehend the dynamics of collaboration.

### **III.3.4. The Normative perspective**

This perspective is absent in all of the research that we have reviewed. Different philosophical viewpoints about education vary about the roles of students and teachers in the classroom in ways that influence the kinds of indicators that would fit to them. This is an aspect that was not examined by any of the literature that we have reviewed. Moreover even if the official goals of the curriculum indicate certain IA indicators as very relevant, the teachers' normative beliefs about the aims of education may affect the learning environment in important ways that influence the way that the IA feedback will be interpreted. This last issue connects the normative with the phenomenological perspective.

### **III.3.5. Issues of generalizability**

From a methodological viewpoint nearly all studies are experiments done away from classrooms. Nearly all use as subjects university students. It would be very difficult to draw results for younger students especially primary school students. Moreover few of the research methodologies are tight enough to lead to results that can be trusted securely. The picture that comes out of this review is the product of repeated and partial evidence rather than secure lessons provided by very tight research.

Two points that have already been mentioned are that a) the methodologies used are not often the most appropriate for a detailed examination of the influence of IA indicators. Especially there is no followup of microprocesses as they unfold in the interacting group of people b) the research is often focused in the feedback of the IA indicators and not in the broader design of the learning environment which might also include concerns about students decoding and use in problem solving of the information provided by the indicators

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