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Knowledge sharing VS construction in online-conversations: a Debate Dashboard to support distributed decision making through the collaborative construction of shared knowledge representations

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Introduction

The ability to collaborate is today one of the crucial capacity that organizations have to possess for surviving in current turbulent and highly competitive environment.

Web 2.0 seems able to offer adequate and more efficient solutions to let organizations to collaborate with stakeholders, customers and employees and other companies. Indeed, on the Internet there are several tools that are able to support large, diverse, and geographically dispersed groups to systematically share, exchange, co-create knowledge and collaboratively come to decisions concerning systemic challenges.

The most common web-based collaborative tools are blogs, wikis, forums, social networks, which were termed *sharing tools* [Josan, Isamil and Boyd, 2007]. The wide successful depends mainly on their ease of use and access. Unskilled technical people can easily participate to the creation and sharing of digital content.

In literature, there is evidence that these tools are very efficient and effective in supporting collaborative tasks at very large scale, such as accumulation, production and exchange of knowledge (e.i. Wikipedia, InnoCentive, Linux), but they have to face also numerous shortcomings when applied for supporting collaborative deliberation and decision making processes around complex problems. One of the main criticism regards the way knowledge is captured and resented. Indeed, sharing tools organize captured content in a chronologically order, that is knowledge representation is based on when the users' contributions were posted. This way to represent knowledge is considered the main cause of several dysfunctions, such as:

- *Low signal-to-noise ratio:* the small-voices are not "listened". They are very crucial because they foster creativity and diversity by bringing new ideas, opinions and perspectives.

- *Redundancy:* the captured content is often unsystematic, overwhelming and scattered. This reduces the possibility to identify relevant information or not well-covered areas, requiring more attention. Additionally, this hampers users to recognize groups' consensus.

- *Conflicts:* opposite views may produce clashes that block conversations (edit wars and flame wars)

- *Lack of navigability:* the captured content is often overwhelming and do not show any connections among related pieces of information. This hinders users to make sense of conversations, in particular way, it impedes new comers to understand and pitch into a discussion started by others.

Other kind of web-based technologies such as prediction markets and e-voting have been proved to be effective at aggregating individual opinions to determine the most widely/strongly held view [Wolfers & Zitzewitz, 2004], but provide little or no support for identifying what the alternatives selected among should be, or what their pros and cons are. Additionally, they do not let users to represent the rationale behind a decision.

In order to address these shortcomings, alternatives technologies, able to support a more structured knowledge and conflicting points of views representation, have been developed. In particular, in this research we focus on argumentation tools. These technologies try to fill the above mentioned gaps by helping groups to represent a debate as a visual map composed of three elements: (i.) a set of *issues* to be answered, (ii.) *positions* (or ideas) as alternative solutions to issues and (iii.) supportive or challenging *arguments* about proposed ideas. Debate is summarized into a visual map connecting *Issues, Positions* and *Arguments* through labelled links such as *supports to, objects-to, suggested by, replaces.* Such tools are supposed to be particularly suited to foster deliberation and decision making processes around complex problems as they allow users to represent contentious and/or competing point of views in coherent structures made up of alternative positions on an issue at stake with their associated chains of pros and cons arguments. Moreover, by providing a logical-based debate representation, and by encouraging evidence-based reasoning and critical thinking, they should significantly reduce the prevalence of some critical pitfalls that usually lead to deliberation failures in small scale groups and promote a more well-supported decision making.

Argument mapping tools also face some important shortcomings. Concerns have been raised about the effectiveness of argument mapping to mediate interaction: a central problem is the presence of communication formats too constraining and intrusive that disrupts the natural flow of free conversations, steepening the learning curve and therefore increasing that users' cognitive effort necessary to participate. The structure of argumentation considers social and conversational cues as irrelevant thus impeding free communications and interaction. This has entailed an objectification and formalization of conversation around the knowledge map, as well as the loss of a range of meta-information about participants and the interaction process through which the content is generated. According to Clark and Brennan [1991], the loss of this meta-information hinders free interaction and makes conversation less efficient.

Therefore, the trade off depends on the lack of tools able to "wisely" mix social cues with knowledge organization formats. Sharing tools provide online users with rich social and conversational information, but they do not support an efficient and effective knowledge organization; on the contrary, argumentation tools support a more structured knowledge organization, but they neglect social cues, hindering free interaction.

Research Question

The research presented in this thesis is motivated by the desire to improve argument-based conversations. In particular, present study aims at enhancing the efficiency of argument mapping technologies in supporting free interaction and mediating web-based conversations among groups of individuals involved in online distributed deliberation and decision making processes. The basic assumption is that online argumentation tools could be the right technologies for supported distributed deliberation and decision making process, but they hamper the free communication.

We approach this by addressing the particular challenge of making argument-based conversations more efficient in terms of communication costs that users have to bear. The supposition is that, by prioritizing the formal representation of contents generated by users, researchers and developers have neglected social and communication aspects which are very important in fostering communication and make participation more engaged. Actually, previous researches on the development of web-based argumentation technologies have focused on the construction of appropriate knowledge format for capturing and displaying users' contribution as well-formed argumentation maps, rather than on the provision of any social and conversational cues that support free and easy interaction and the creation of proper knowledge object. This has raised concerns on the capability of argumentation to act as effective mediator and facilitator of interaction, notwithstanding the remarkably advantages that are expected from its use.

In this work the aim is to investigate how social and conversational argumentation technologies capabilities can be improved, and whether and to what extend these improvements impact on users' performances. Put differently, the aim is to improve the mediation and interaction capability of argument tools by supporting common ground construction and updating during argument-based conversations. With this in mind, the central research question is:

How to retain the advantages of argument mapping and improve their mediation capability?

Literature Overview

Providing an answer to the question above implies constituting a theoretical basis for better evaluating the strengthens and weaknesses of argument mapping tools.

Literature has showed that argumentation technologies respect other current traditional online tools, are able to support effectively deliberation and decision making processes. Online argumentation tools make use of the argument theory to mediate and represent debates. Argumentation theory deals with how humans should and do reach conclusions through reasoning. It is based on the idea that every opinion can be broken down into sub-elements that play certain inferential functions in the discourse, such as the conclusion or claim of an inference and the premise that leads to it.

An argument map can be defined as a visual representation of an argumentation in which the functional relationships among claims are made wholly explicit using graphical or other non-verbal techniques [van Gelder, 2003]. The term "*argument mapping*" indicates the act of producing such maps, as well as modifying, viewing and sharing them.

On the Internet, there are numerous examples of web-based collaborative argument mapping tools (for a review of current tools see http://events.kmi.open.ac.uk/essence/tools) that allow users to navigate, co-create and edit an argument map. Online collaborative argument mapping tools can be used to visualize concepts, content (e.g. annotations), knowledge resources (e.g. websites), as well as links between knowledge elements. The main feature of argument maps is that they allow users to present complex reasoning in an easy to follow, clear and unambiguous way. The basic assumption behind this approach is that displaying knowledge visually through a spatial metaphor, is helpful for key cognitive tasks such as sense-making of large amount of (conflicting) information [Uren et al., 2006] and localization of relevant information. Additionally, such spatial-visual representation supports evidence-based reasoning [Bex *et al.,* 2003] by presenting content in a concise manner and making the logic behind an analysis more evident. By providing a logical-based debate representation, and by encouraging evidence-based reasoning and critical thinking, should significantly encourage individuals to make well-grounded and reasoned decisions, further to avoid some critical pitfalls that usually lead to deliberation failures.

Nevertheless all these advantages and the positive impact on organizational knowledge management and in particular way on deliberation and decision making processes [Conklin, 2003; van Gelder, 2003; Tergan, 2003], they seem to struggle to reach widespread diffusion both in the small and large organizations.

In this research we think that the limited success of online argumentation as a collaborative technology depends mainly on the fact that these tools neglect social and conversational aspects that, in reality, make conversation easier and more engaged. This has entailed the loss of a range of meta-information about participants and the interaction process through which the content is generated, hindering interaction and makes conversation less efficient [Clark and Brennan, 1991].

According to Clark and Brennan [1991], during a conversation, participants exchange, in addition to information, evidence and/or requests for evidence needed to understand if the listeners have understood or have not understood what the speaker has said [Clark and Brennan, 1991]. Once such evidence is gained through conversational feedback offered by verbal and nonverbal communication acts, it is used to update participants' shared information. The process of making the understood information part of participants' mutual knowledge, beliefs, and assumptions is called *grounding process*. The effective construction of mutual knowledge is a necessary condition for a successful conversation and knowledge accumulation and transformation. Greater amount of common ground — leads to more efficient communication, coordination, collaboration and performance [Clark, 1996; Convertino *et al.*, 2005].

When the conversation is mediated by any kind of communication technology, part of the conversational feedback provided in face to face discussion is either unavailable or can be provided with some extra communication effort. Consequently the theory of common ground states that mediated communication is always less efficient than face to face interaction and inefficiency is characterized in terms of grounding costs. In line with this, in the case of argument mapping tools, the common ground building process is very complicated and cognitively costly.

Clark and collaborators [Clark and Brennan, 1991; Kraut *et al.,* 2001] proposed that specific communication contexts can be described in terms of sets of grounding constraints (Table I.1). These constraints are desirable to reduce the ambiguity and grounding costs in conversation. Indeed, the higher the number of missing constraints, the less able the medium will be for facilitating common ground building and efficient communication.

Table I.1. Affordance in communication media

Affordance	Clark *et al.'s* definition	Our adapted definition
Audibility	Participants hear other users and sound in the physical environment	Participants hear other users and sound in the virtual environment
Copresence	Users share the same physical environment	Participants are mutually aware that they share a virtual environment
Cotemporality	B receives at roughly the same time as A produces	Participant receives the message at roughly the same time as the other produces (in real time)
Mobility	Users can move around physical space	People can move around in a shared virtual environment
Reviewability	B can review A's message	Message do not fade over time but can be reviewed
Revisability	B can revise message for B	Message can be revised before being sent
Simultaneity	A and B can send and receive at once and simultaneously.	Participants can send and receive messages at once and simultaneously
Sequentiality	A's and B's turns cannot get out of sequence.	Participants can understand and see the reply structure
Tangibility	Participants can touch other people and objects in the physical environment	Participants can touch other people and object in the virtual environment
Visibility	A and B are visible to each other	Participants see the actions of the others user in the shared virtual environment

Following Clark and Brennan's theory, we evaluate argumentation technology in terms of the techniques it allows building common ground and thus in terms of grounding costs that users have to bear to communicate in an efficient way. In particular, in the case of argument mapping tools, grounding cost is very high since eight out of ten constraints are missing.

Therefore, the main reason for a poor mediation and communication performances of argument mapping tools in terms of grounding costs is that they are objected-oriented technologies: the primary objective of an argument mapping tool is to generate a knowledge object in the form of map able to capture and organize knowledge provided by many contributors during a debate. Differently from other collaboration technologies, they are not explicitly designed to support interaction and keeping track of the communicative acts developing during the process. Therefore, technology mediation, object-orientation, formalization and spatial reorganization of information entail high grounding costs and consequently difficulties in developing common ground and support efficient/effective communication.

The difficulties of building common ground may prevent users to exploit the benefits usually associated to the use of argumentation technologies; such benefits actually assume the availability of well-formed maps or at least that users are in the conditions to create such maps.

If grounding costs are high, the chances for users to create good maps will be low, unless substantial effort is provided by external moderators charged with the task of mapping in real time the contributions provided by many users. Unfortunately moderation can become very costly when the users' number is not small.

In order to tackle this problem the idea is to develop an augmented argument mapping tool able to retain the traditional advantages offered by argumentation technologies and to deliver at the same time a richer set of meta-information aimed at fostering social interaction among users and supporting the construction of mutual understanding. We call such an "augmented" Debate Dashboard because the meta-information is delivered mostly through visual widgets, built upon and connected to the argumentation tool, that are expected to support participant conversations. The basic idea of the Debate Dashboard is to make visible information that in face-to-face conversation is immediately available, while in computer mediated communication are hidden or missing.

Numerous researchers have been focused on the analysis of the impact of conversational feedback and hidden information on quality of discussion, its outcome and interaction processes among users. Shneiderman [2000] argued how disclosing patterns of past performance, providing rich feedback about users and generated content are best practices for supporting online conversations. Erickson *et al*. [2002] discussed the importance of making socially-relevant hidden information visible in interactive communities in order to support smooth, reflective and productive conversations through synchronous and asynchronous tools. Other researchers have built systems attempting to provide large amount of information about the presence and activity of their users in a consolidated and easy-to-read way. [Donath *et al*., 1999; Viegas & Donath, 1999; Dave *et al*., 2004; Suh *et al*., 2008].

Our goal is to set up a Debate Dashboard in order to aid users to monitor and make sense of discussions, showing them feedback about participants, their activities with respect to the conversations and the evolution of the generated content. In other words, drawing on *grounding cost theory*, we defined three categories of feedback that are supposed to reduce collaborative cognitive effort, as well as foster grounding process:

- **Community** (who): this set of feedback allows users to know who are the community members, to visualize the community structure and to develop a sense of membership [Kim, 2000].
- **Interaction** (how): this class of feedback allows users to understand how the members of online community interact and what is happening in the online community.
- **Absorption of knowledge** (what): this feedback is about the content generated through interaction among users and its organization.

As already mentioned, by providing such conversational feedback it is possible to support the construction of mutual understanding which is usually carried by verbal and nonverbal communication acts in ordinary conversations and is partially lost when conversation is mediated by a technology.

These classes of feedback are supposed to support users in communicating in better and easier ways, reducing misunderstandings, facilitating the grounding process and diminishing its related costs. Moreover, we expect that the improvement in the grounding process may also improve some users' performances such as efficiency and outcomes.

The feedback are provided through different visual widgets whose features were defined on the basis of results of both a literature review on thirty already implemented visualization tools and a survey of the most famous social networks, chats, blogs such as Twitter, Skype, Facebook etc.

All the visualization tools, that compose the Dashboard, work in a closely coupled way, therefore any manipulation and change of values in one view creates a similar change in the linked ones. This allows users to look at data through different perspectives, perceive new information and discover new insights.

The Debate Dashboard has been built upon a web-based argument mapping tool, namely Cohere and an experimental version is available at http://socialmap.open.ac.uk/.

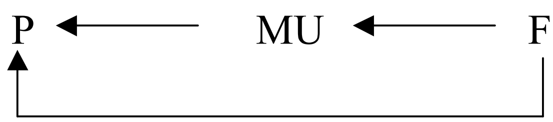
Cohere is a web-based asynchronous argument mapping tool whose purpose is to support an on-line collective argumentative debate. This argument mapping tool applies the IBIS approach [Issue Based Information System, Kunz & Rittel, 1970]. With Cohere users can create posts to express their thoughts and pick up an icon to associate to them, which explain the rhetorical role of that post in the wider discussions. Moreover with Cohere users can explicitly connect their post to other post which is relevant to what they want to say. By structuring and representing online discourse as semantic network of posts Cohere enables a whole new way to browse, make sense of, and analyze the online discourse.

We chose Cohere for the evaluation test because it is already able to provide some of our individualized feedback. This implicates minor effort to make the platform adapted to our aims. Another important reason for which we chose Cohere is that it is a web-based asynchronous argument mapping tool. The asynchronicity makes remote, mediated conversation, as well as the grounding process, more complicated. Therefore, the utilization of feedback in this context makes sense and could be even more appropriated, as well as more challenging.

Experiment

This study wants to test the impact of visual conversational feedback on Mutual Understanding (MU) and, in turn, the impact of MU on users' performances, using online collaboration argument mapping tool.

In Figure I.1, we represent the hypothesis graphically:



Legend:

P Performance
MU Mutual understanding
F Feedback
← Affect positively

Figure I.1. Simplified Theoretical Model

Through this experiment, beyond to evaluate if visual feedback improves and support the MU, we aim at evaluating the impact of MU and visual feedback on three different kinds of performance (P), that is:

- **Usability:** The variables considered are perceived ease of use, user satisfaction, perceived usefulness [Davis, 1989; Venkatesh and Davis, 2003]

- **Quality of collaborative process:** This variable is measured through the users' perceptions of quality of collaboration, the "amount" of collaboration (number of connections created during online discussion)
- **Quality of outcome:** This variable is measured through the users' perceptions and misalignment between the group decision and "the right solution"; in other words the aim is the measuring the accuracy of the group decision.

Procedure

In order to test the hypotheses, an evaluation of the impact of the visual feedback provided through the Debate Dashboard on grounding process and on users' performance, such as quality of collaboration, quality of outcome and Cohere usability was performed in June 2011 at the University of Naples with a community of around 60 undergraduate students. The students were all part of the same class from a graduate program in Industrial Engineering, age 19-22. Students participated in a single-factor, asynchronous, web-based group decision making experiment. Participants were randomly assigned to two groups (A and B). The group A was composed of 25 students, 56% male; the group B was composed of 36 students, 64% male. Each group worked on a specific collaborative decision making task for two weeks. The decision making tasks are economic problems that required students to forecast the value of an economic variable within the allotted time. In our case, students have forecast the oil and gold price in the short period (three months). During two weeks, each group developed and worked on a collaborative map that reflect knowledge, perspectives and opinions of users, as well as support collective decision making process on their specific task. The field test was based on between-subject design with two groups which have been used only once and be part of treatment group or control group. The members of the treatment group (group A) used an "augmented" version of Cohere (http://socialmap.open.ac.uk/), that is an argument mapping tool integrated with the visual widgets (the Debate Dashboard). Table I.2 shows how each feedback has been implemented and what feedback could not be realized because of technical features of Cohere and time constraints.

Table I.2. Affordance in communication media

Affordance	Visual Widgets
Copresence	List of users. Users online are green, while ones offline are red (People&Group tab on Cohere Home Page and on Group Page)
Cotemporality	Not provided
Mobility	Not provided
Simultaneity	Not provided
Sequentiality	Not provided
Visibility	Stats about users activity (Stats tab →Users tab on Group Page)
Profile	User's personal page
Community history	Stats about created ideas (Stats tab →Ideas tab on Group Page)
Social Structure	Social network visualization (Social Network on Group Page)
Contextualization	TagCloud search engine (click to each TagCloud to visualize all the ideas with that TagCloud)
Relevance	TagCloud (TagCloud tab on Home Page and Tags tab on Group Page)
Structuring	Argument map

Moreover, we tracked and recorded users' activity in order to monitor and collect data on what feedback they used, as well as their frequency of use. The members of control group (group B) used a "plain" version of Cohere (http://litemap.open.ac.uk/), that is without the new introduced feedback. Before starting the experiment, there was a preparatory phase, during which students had four 2 hours of seminars about: i. Collective intelligence and its current Internet applications; ii. Argumentation, with a focus on IBIS format; iii. The main characteristics defining the Gold and Oil Market; iv. An instructional demo of the Cohere. The students were also given few readings materials: newspaper and magazines articles the topics. Moreover, a warm up phase of one week was performed during which users could use and practice with the new formalism. After the completion of decision tasks, the members filled out a follow-up questionnaire. The questionnaire is made up of 28 psychometric scale measuring participants' perception about quality of collaboration, the outcomes, Cohere usability and mutual understanding.

Measurements

In order to evaluate the impact of visual feedback on Mutual Understanding and on users' performances, we have to measure the four following variables. In particular:

- **Use of Feedback**: was measured through the frequency of feedback utilization. We collect this data by using Virtual Machine (developed by a research group of Universidad Carlos III) able to track and record users' online users' activity (users' chronology). In this way, we could compute the use of feedback for each user (frequency).

- **Mutual Understanding**: was measured through Likert scales by administering a follow-up questionnaire.

- **Quality of Collaboration**: was measured through Likert scales by administering a follow-up questionnaire and through a quantitative measurement as number of created connections (Information broker + Compared thinking)

- **Quality of Decision:** this variable was measured through Likert scales by administering a follow-up questionnaire and through a quantitative measure, that is the accuracy of students' foresight

- **Usability:** this variable was measured through Likert scale by administering a questionnaire.

Data Analysis

This dissertation use Structural Equation Modelling to analyze the theoretical model.

The main multivariate regression techniques share one common limitation: each technique can examines only single relationship at a time [Hair et al., 2006]. These "traditional" techniques do not enable us to test the researcher's entire theory with procedures that consider all possible information.

Structural Equation Modeling (SEM) is a family of statistical models that seek to explain the relationships among multiple variables. It can examine a series of dependence relationships simultaneously. So, a hypothesized dependent variable becomes independent variables in subsequent dependence relationship. SEM has several advantages over first generation technique like principal components, factor analysis and multiple regressions. First, SEM allows researchers to model relationship among multiple predictor and criterion variables [Chin, 1998]. Second, SEM enables researchers to measure latent (unobservable) variables. Third, SEM allows researchers to assess the measurement models and structural models simultaneously. Thus, measurement errors can be analyzed as part of the model. Finally, SEM estimates a series of separate, but interdependent, multiple regression equations simultaneously by specifying a structural model. These attributes enable researchers to answer a set of interrelated research questions in a single, systematic, comprehensive analysis [Gefen et al., 2000]. Consequently, as SEM is well suited to modeling complex processes, we think that it is well adapted to the analysis of our theoretical model.

Researchers have two methods of SEM analysis to choose from, such as covariance-based SEM or least squares-bases SEM. PLS was chosen over the other one because PLS support exploratory research and the data distribution assumptions are less stringent than the assumptions behind covariance-based SEM. Additionally, PLS is capable of assessing indirect effect such as the mediation role of Mutual understanding between use of feedback and users' performances.

Results

Recall that the overarching goal of this dissertation is to investigate the influence of visual conversational feedback on MU and, in turn, the impact of MU on users' performances (quality of collaboration, quality of decision and usability).

For data analysis, three different databases were used, in particular:

- **Cohere database.** It includes all data regarding users' activity performed on Cohere platforms (group A and group B).
- **Follow up questionnaire database**. It includes data collected through the follow up questionnaire administered to all participants at the end of the experiment (group A and group B)
- **Virtual Machine database.** This database contains only data related to students of Group A. By using the virtual machine, the use of each feedback has been tracked and recorded through their respective URLs. It was possible, because each visual widget, by which we provide different individualized feedback, has an own web page and, thus, an URL (only group A).

Each of these databases has been analyzed to test our hypothesis and each analysis has confirmed as we supposed and expected. In particular, from the analysis of Cohere database is emerged that group A worked more than group B notwithstanding group A is smaller than group B (respectively 25 and 36) (Table I.3).

Table I.3. Descriptive statistics – Cohere databases

User's activity – Group A		**User's activity – Group B**	
# Posts	269	# Posts	334
# Connections	412	# Connections	380
Total	681	Total	714
Average	27,24	Average	18,31
St. Deviation	22,98	St. Deviation	16,28

One-tail T Test on users' activity level confirms that group A was significantly more active than group B. By using follow-up questionnaire made up of 28 psychometric scales, it has been possible to measure and collect data about crucial variables of theoretical model, such as quality of collaboration, quality of decision, usability and mutual understanding. By performing one-tail T test for each latent construct of questionnaire, it is emerged that users' performance and Mutual Understanding building of group A are always significantly better and greater than users' performance and Mutual Understanding of group B.

From these analyses, we can conclude that the group A, which used the Debate Dashboard, had better performance than the group B that used the plain version. As the two groups were not significantly different (it was tested through t Test on an academic performance indicator) we can conclude that the better performance depends on the provision of individualized feedback.

Further analysis were performed to understand the role and the impact of each feedback on common ground building and users' performances, as well as, the mediation role of mutual understanding in improving users' performances. In particular, in order to test the proposed theoretical model, based on a set of statements of correlations between variables, the Structural Equation Modelling was used. In other words, by using SEM techniques, we aim at measuring the impact of visual feedback on MU and, in turn, the effect of Mutual Understanding on the three level of performances, namely Quality of Collaboration (QofC), Quality of Decision (QofD) and Usability (Usab), as well as the impact of feedback on users' performances.

In this third phase of data analysis, we used only Group A databases. From SEM analysis is emerged that our hypothesis are supported. In particular, it is possible to claim that visual conversation feedback impact significantly on increase of mutual understanding among online users over time. Additionally, visual feedback impact significantly on level of users' performances.

By using SEM, it has been possible to verify the mediation role of Mutual Understanding. In particular, mediation occurs when the cause-effect relationship between a predictor variable (use of feedback) and a criterion variable (users' performances) happens through an intervening variable (Mutual understanding). Mediation relationships are of interest because they go beyond simple describing correlations to explain how process work. The hypothesized mediation effects were tested using PLS. In order to perform the mediation analysis a simple model was created that depict a relationship between the independent variable (use of feedback) and the dependent variable (users' performances). Then, a second model was created that include the mediator variable (Mutual Understanding). The results demonstrate that the R^2 of the mediated model was higher than the simple model (Table I.4). The mediated model explains more of the variance of users' performances than simple models. In nutshell, Mutual Understanding mediates effectively the interaction among feedback and users' performances. The results are summarized in Table I.4.

Table I.4. R^2 comparison

Path	**Simple Model R^2 (without MU)**	**Mediated Model R2**
COMMUNITY --> MU --> USAB	0,544	0,605
INTERACTION --> MU --> USAB		
ABSORPTION --> MU --> USAB		
COMMUNITY --> MU --> QofC	0,602	0,71
INTERACTION --> MU --> QofC		
ABSORPTION --> MU --> QofC		
COMMUNITY --> MU --> QofD	0,312	0,318
INTERACTION --> MU --> QofD		
ABSORPTION --> MU --> QofD		

Implication

This study aims at improving argumentation mediation capabilities in order to exploit their inherent advantages and, at the same time, fostering free interaction among online users. To address this limitation, a Debate Dashboard has been implemented. It is made up of a set visual widgets able to provide feedback about users, interaction process and generated content.

Through a field test, we tested three four of hypotheses: i. the impact of visual feedback on Mutual Understanding, ii. the effect of Mutual Understanding on the users' performances, iv. the impact of feedback on users' performances. iii. the hypothesized mediation effects of Mutual Understanding between feedback and users' performances.

The results confirm as supposed. Generally, group A show a significantly better performances (QofC, QofD, Usab) and MU than group B. Additionally, it is emerged that visual feedback impacts on increasing of Mutual Understanding and on users' performances. Mutual Understanding affects users' performances and mediates (affect positively) the relationship between feedback and performances.

Practical and theoretical contributions has emerged from this study. First, the findings from the analysis of structural equation model confirm that visual, social and conversational feedback impact on mutual understanding and on users' performances. Second, the results indicates that mutual understanding has a role of mediator and catalyst among visual feedback and users' performances. Third, in order to support efficient and effective distributed decision making process, online collaborative tools have to be able both to foster free interactions and to aid a more structured knowledge organization. Socialization/Interaction and knowledge organization are two crucial condition for supporting deliberation and decision making successfully. Last, this study can be considered as an initial step in the development of better platform able to leverage the wisdom of different distributed individuals.

Limitation

The first limitation of this research is that participants were drawn from a single academic course. The second limitation of this research is the size of samples. Indeed, the basic idea is to expand the samples in order to better measure the effectiveness and efficiency of visual feedback in mediate and support large discussion groups. The third limitation of this study is that we did consider in our analysis demographic variables that could be inserted in SEM models. The fourth limitation of this dissertation regards the use of Likert scale to collected data and, in particular, of close-ended questions. Indeed, this type of questions could lead users to give responses not reasoned or for satisfying the interviewer, lead to inaccurate data analysis and results. one of the main criticism is that Likert scale uses close-ended questions. The last limitations regard the set up of Debate Dashboard; indeed, not all individualized feedback was been implemented because of technical Cohere features. Any analysis or studies has been run about the design of visual widgets used.

Conclusion

The satisfactory results represent an important encouragement to extend this work and to conduct further experiments enlarging the sample and involved expert communities. A significant common ground building through argumentation represents an important motivation to make comparison test with alternative tools. Additionally, we aim at implementing the other individualized feedback, in order to have a more complete and detailed idea about the role of different feedback. Another important future step could be the improvement of the design of current visual widgets in order to better support user's grounding process.

Chapter 1
Web 2.0: It is not a fad, but the new normal

1.1 Introduction

The year 1989 witnessed one of the major and most important events for human history: the invention of the World Wide Web by Tim Berners-Lee. Dispersed computer communicating through packet-switching network allowed scientific researchers of the CERN to communicate and to be linked. This invention was transforming human communication and production of knowledge [Harnad, 1991].

The advent of World Wide Web, later made it more accessible by Mosaic browser and its successors, produced a hyperlinked system of documents through which to present visual information as well as to connect users to a powerful range of knowledge. These technological innovations have transformed the computer into a revolutionary new medium for interpersonal, group and mass communication and have introduced users to a dazzling array of new communicative capabilities. The Web is changing the way the world is doing things efficiently.

1.2 A social revolution: the Web 2.0

On the 25th of December 2006, the TIME magazine assigned the title of the “Man of the Year” not to a particular personality, but to the Internet user. The choice of TIME Magazine to prize this grass-root phenomenon is a good indication of how intensively this trend has permeated our culture. Indeed, the article emphasized how the phenomenon, commonly termed as Web 2.0, is affecting the way individuals communicate, collaborate, learn, entertainment themselves, make decisions, create and share information.

> *It's a story about community and collaboration on a scale never seen before. It's about the cosmic compendium of knowledge Wikipedia and the million-channel people's network YouTube and the online metropolis MySpace. It's about the many wresting power from the few and helping one another for nothing and how that will not only change the world, but also change the way the world changes* [Grossman, TIME Magazine U.S].

The term Web 2.0 was proposed by Tim O'Reilly [2005] to indicate cutting-edge web developments. Actually, though the term suggests a new version of Web technology, it refers instead to changes in the communicative uses of the underlying platform. As Berners-Lee affirms, Web 2.0 offers nothing radically new since the potential for a high level of participation and collaboration has always been inherent in the web from its outset [Clarke, 2006; Laningham, 2006]. The crucial changes were certain technical improvements, which have allowed users with little technical skills and knowledge to construct and share their own digital products through the new platform. Indeed, the Web 2.0 applications are considered simple, at least from users' perspectives. Thus, the lowering of technical barriers seems to be the main reason of Web 2.0 huge participation and of its widespread adoption.

In this work, the adopted definition of Web 2.0 is:

> *"Web 2.0 is the network as platform***,** *spanning all connected devices; Web 2.0 applications are those that make visible the most of the intrinsic advantage of these platforms, that is delivering software as continually update service that gets better the more people use it, consuming and remixing data from multiple sources, including individual users, while they provide their own data and services in a form that allows remixing by others, creating network effects through an "architecture of participation" and going beyond the page metaphor of Web 1.0 to deliver rich user experience"* [O' Reilly, 2005]

Perhaps, the most compelling aspects of Web 2.0 platform, which differentiate it from the first generation of the Web, are the *role of users* and the new "*architecture of participation"*. In Web 1.0, the content creators were few and the vast majority of users simply acting as consumers of these materials; instead in Web 2.0 any participant could create content and numerous technological aids have been implemented to maximize the potential of this phenomenon. While the earlier Web allowed people to publish content, which often ended up in isolated information silos, the new Web's architecture allows more interactive forms of publishing of any kind of digital content (both textual and multimedia), participation, and networking through very common collaborative technologies, such as blogs, wikis, forums, social network sites. This architecture is based on software, where users generated content and its organization appears spontaneously through the action of millions of users. Additionally, the system is designed to take users' interactions and utilize them to improve itself. Bit Torrent, for instance, demonstrates this key Web 2.0 principle; that is the network of downloader provides both the bandwidth and data to other users so that the more people participate, the more resources are available to the other users on the network. User is a vital factor for all categories of Web 2.0 applications, not only as a consumer, but mainly as a content contributor. Indeed, people play an active role in generating and pooling knowledge that they share each other, which is subsequently remixed, re-distributed and re-consumed by others [Harrison and Barthel, 2009]. The Web is principally about participating rather than about passively receiving information [Tapscott and William, 2006] and it is inherently social so that users are central to both content and form of all material and resources [Hardey, 2007]. This feature makes Web 2.0 a "live" medium, which is constantly updated and enriched by users with new digital products, information and knowledge. On the Internet different collaborative technologies exist. In the following, a basic classification based on application types divided into eight categories is proposed:

- *Blogs:* the most known and fast-growing category of Web 2.0 applications. They are online journal where users can publish content. Often, blogs are combined with *podcasts,* that is digital audio or video. One of the most famous blog is Slash.dot [http://slashdot.org/].

- *Wikis:* is a webpage or a set of webpages that can be easily edited by anyone who is allowed access. Wikis are widely recognized as tools able to support collaborative work. The most famous wiki is Wikipedia, the largest encyclopaedia of the world (http://www.wikipedia.org).

- *Social Networks:* allow users to build a sort of personal websites accessible to other users for exchange of personal information and content and for communications. They can be professional or social networking sites that facilitate meet people. They are the most popular web-based applications and people spend the most part of their Internet total time visiting them. Examples are: http://facebook.com/; http://myspace.com/; http://ning.com/.

- *Content Communities:* allow users to organize and share particular type of content. Examples are applications of video sharing (e.g. http://youtube.com) or photo sharing (e.g. http://flickr.com, www.digg.com).

- *Forums/bullet boards:* let users to share ideas and information usually around specific interests.

- *Data mash-ups:* pull together data from different sources to create a new service. The main characteristics of the mash-ups are combination, visualization, and aggregation. It is important to make existing data more useful for personal and professional use.

- *RSS and Syndication:* is a family of formats which permit users to fully customise the web content that they wish to access. Information from the Website is collected within a feed and "piped" to user in a process known as syndication.

- *Tagging and social bookmarking:* a tag is a keyword that is added to a digital object (photo, video, websites) to describe it. One of the first large-scale applications of tagging was seen in del.icio.us website, which launched the social bookmarking' phenomenon. Social bookmarking allows users to create lists of favourite, to store them centrally and to share them with other users of the systems.

Web 2.0 is pervasive and it is radically modifying the way people communicate, find and share information and collaborate to create collective outputs. Being connected to the world around us has never been more easy and accessible than it is today. The ubiquity of the Web 2.0 has revolutionized how we interact with each other. From the advent of email, bulletin board systems, to current social networking sites, technology has been increasingly integrated with communication to become a prominent focus of the new digital age. It has led up a "social revolution" that is taking over the Internet and entering into our real lives. Indeed, Web 2.0 technologies are able to affect individual's behaviours and their decisions and choices. At the beginning, many researchers and practitioners claimed that Web 2.0 would have been only a trend that would be gone away in few time. But it is still here and it is clearly the *new normal*. In order to better understand how Web 2.0 applications are the new normal and, in particular, how web 2.0 technologies have deeply revolutionized our daily life, in the following some web-based stories, proving their intense impact, will be presented. These examples emphasize the way Web 2.0 technologies have changed how we communicate, interact and create collective output.

One of the most famous examples of collaborative knowledge building systems is Wikipedia with more than 400 millions of unique visitor monthly. It is an online encyclopaedia in which any reader can also be an editor, with their changes immediately visible to subsequent visitors. Its slogan is *Anyone Can Edit* – even unregistered people can contribute to the construction of knowledge base. Millions of anonymous and voluntary users create and update daily article pages of largest encyclopaedia of the world. This massive participation (there are more than 82.000 active contributors) has resulted in a highly popular site with a large amount of content translated in 270 different languages and with nineteen millions of articles (almost one million of article in Italian Wikipedia alone). Through this successful story, I would like to emphasize how Web 2.0 collaborative technologies has made possible to thousands of individuals to collaborate to the creation of the largest encyclopaedia of the world. Indeed, English Wikipedia version counts around 4 millions of articles and 609 millions of words, exceeding Britannica Encyclopaedia which in December of 2004 counted 120,000 articles and 77 million words. Web-based technologies have made possible such level of participation and collaboration, which was unimaginable few years ago.

In 2009, Twitter was an efficient means to surpassing the censure that Iranian Government applied during the movement against the elections results. Twitter was launched in 2006 and allows “twitters” to post what they want in a message made up of not more than 140 characters. Once that the message is sent, all subscribers who follow him/her receive updates. Because of Iranian censorship on information flow through the media from the country, supporters of the Mir-Hossein Mousavi protested against the results of the elections that were in favour of Ahmedinejad by using Twitter. What makes Twitter suitable tools for a mass protest was both its ease of use and very hard for any central authority to control. Additionally, by using hash tag users can tag their posts facilitating their grouped and search for topic, as well as their retransmission by other users. Twitter has broadcasted what had happened in Iran. Clearly, Twitter did not start the protests in Iran, nor did it make them possible. But surely it has encouraged the protesters, reinforced their conviction that they are not alone but populations outside Iran were engaged and followed their situation in a way that was never possible before [source: Grossman, 2009, TIME Magazine].

Hundreds of thousands of activists contributed to Barack Obama’s electoral campaign playing a significant role in influencing the electoral outcome and now pursuing open-lobbying on the Presidential agenda through the Internet. Many consider that Barack Obama is the first "Social Media" President. A new age of digital democracy where people play an active role in government now and over time is beginning. In June 2011, The White House published a blog post that indicates that the White House is indeed listening in social media. Through web-based collaborative technologies government and leaders could encourage fans and followers to contribute to any campaign or mission. In doing so, Web 2.0

technologies evolve from information channels to engaged communities with the ability to affect people's behaviours. Through Internet-based application the future of politics isn't created, it's co-created [source: Soris, 2011 - FastCompany].

Facebook was launched in February 2004 and the Web site's membership was initially limited Harvard students. More than half of 19.500 student college signed up within the first month. Today, Facebook counts more than 800 millions of users around the world. It is the size of the entire Internet in 2004. It is the top online destination in a lot of countries around the world (e.g. USA, UK, Italy, Brazil, Germany, France), becoming synonymous with Web 2.0 use [Nielsen report, 2011]. People use Facebook everyday to keep up with friends, upload an unlimited number of photos, share links and videos, and learn more about the people they meet. Users are experiencing a new way to stay constantly in contact with others. In general, by using social networking sites, online users continually update their status and share their moment-by-moment activities. We are living in a society, where we share almost everything: what we eat, where we shop, what we are watching on television. Slowly but surely everything is losing its status of "sacred", secret, with sharing becoming the norm. Social scientists called this incessant online contact "ambient awareness". In some way, through this constant updating, it is like being "physically" near someone and picking up on his mood through things they do. By aggregating all the updates, snippets coalesce into a surprisingly sophisticated portrait of our friends' and family members' lives. Being tightly connected to the world around us has never been simpler than it is at the moment. Internet made possible to reach people with merely a click of button, but social networking sites have made the world smaller!

These are only few examples about how Web 2.0 technologies have provided users with new forms and spaces for social interactions, community formation and social and professional network creation and maintenance. As emerged, these new applications and services have had an enormous impact on how information is processed, published and "consumed" by users, as well as they have meaningfully modified the way in which users interact each other and with the tools. Finally, all indications point to the fact that Web 2.0 applications and services are here to stay. It is not a fad, but the new conventional ways to interact, communicate and collaborate on a scale never seen before.

1.3 Web 2.0 in organizations

Clearly, such social revolution has had a very profound impact also on business world. The great success of new Web 2.0 applications and services has encouraged organizations to rewire the way they think about and run their businesses. Since its advent, the second generation of the Web has enabled new ways for companies to connect the internal effort of employees, build relationship with suppliers and stakeholders, reach their customers and promote their brand. Increasingly, organizations are exploring new modes to leverage open and diffusion collaboration as a new competitive approach. Applications like blogs, wikis, prediction market, mash-ups and social networks have rapidly been adopting by the enterprises.

Tapscott and Williams [2006] claim that Web 2.0 has propelled the business world in a new era, one of the *Mass Collaboration.* Indeed, the openness, scalability, self-organization, loose-coordination and adequate, low cost collaborative tools have allowed large groups of users to achieve outstanding results in knowledge creation, exchange and sharing, such that they are become a source of inspiration for both organizational researchers and firms [Gloor, 2006; Raymond, 2001; Tapscott and Williams, 2006, von Hippel, 2001; von Krogh and von Hippel, 2006]. New business approaches are already developed and established, which impact on the way organizations manage different organizational processes. In particular, organizations are using these new collaborative technologies for fostering innovation, supporting marketing and knowledge management strategies, aiding problem solving and decision making processes. Mass collaboration is encouraging customers, employees, suppliers partners and competitors to share knowledge and ideas. This is radically modifying the traditionally accepted business models. Vertically organized hierarchies and closed business systems are giving way to flat organizations and open platform. Collaboration is nothing new, but what has changed since the advent of Web 2.0 tools has been its breadth and its depth.

In 2006, Andrew McAfee, a Harvard Business School, suggested the term “Enterprise 2.0” to describe and indicate *those platforms that companies can buy or build to make visible the practices and outputs of their knowledge workers*. Web 2.0 platforms are providing enterprises with new models and tools for sustaining and improving collaboration and co-creation, accumulation and sharing of knowledge. These collaborative technologies are considered the new, right tools for knowledge work. Wikis, blogs, group-messaging software and the like can make an organization intranet into a constantly changing structure built by distributed, autonomous peers [McAfee, 2006]. Not only workers can collect a huge amount of knowledge and self-identify the contents that are most relevant for their activity but they are also able to set up the structures and the collaborative processes that are adequate to their needs. In this way, virtual collaborators co-design collaborative platforms that reflect the way work really gets done [McAfee, 2006]. Other important aspects of Enterprise 2.0 technologies are their adaptability and flexibility to the different work applications; they do not impose on users any preconceived notions about how to work, how structured and categorized the generated content, but they leave that these aspects of knowledge work emerge spontaneously. Definitely, the wide adoption of web-based technologies derives also from the failure of traditional Knowledge Management tools which characterize to be too rigid, formal and structured. In fact, in his studies, Davenport [2005] found that all knowledge workers surveyed are not satisfied and happy to use the platforms and channels available to them, such as Intranet, corporate Web site, Information portals, e-mail and person-to-person instant messaging. Additionally, a second more crucial problem of traditional Knowledge Management tools felt from workers was that such technologies did not a good job of capturing their knowledge; indeed they do not let them to easily acquire, share and re-use organizational knowledge. On the contrary, the new web-based applications let workers an informal, less structured and more spontaneous knowledge-based work of organizations.

Other two important advantages deriving from the use of Web 2.0 technologies are:

- letting team members, geographically dispersed, to collaborate [Hayden, 2004], capture, exchange and share knowledge in easier, cheaper and more pervasive way than traditional Knowledge Management systems [Duffy, 2000], without any time and space constraints.
- permitting organization to forge closer relationships with customers, suppliers, business partners and stakeholders, which are essential for success and survival in increasingly turbulent and highly competitive environment [Baum, Calabrese and Silverman, 2000; Dyer and Nobeoka, 2000;].

In general, by collaborating, organizations learn from others, share resources, risks and costs, access to new and diverse knowledge, know-how, competencies and perspectives and develop new opportunities.

Nowadays, the use of Web 2.0 technologies in the organizations is a new reality. Indeed, as emerged from McKinsey survey on Business technology [2011], one-third of respondents (3.249 executives across a range of regions, industries and functional areas) uses Web 2.0 technologies in their organizations. The share of companies that employs web-based technologies continues to grow, in particular with regard to utilization of social networking (40%) and blogs (38%). From McKinsey survey results emerges that the main measurable benefits deriving from the use of Web 2.0 are the increase speed of access to both internal and external knowledge and expertise (respectively 77% and 57%), the reduction of communication costs (60%), the increasing of employees, customers and partners satisfaction (respectively 41%, 50%, 45%), as well as the increasing of effectiveness of marketing politics (63%) and the reduction of operational and marketing cost (respectively 40% and 45%) and of time to market of products/services (29%).

Blogs, wikis, forums, social networks and the like let organizations to capture the power of participation and collaboration. With the so-called Enterprise 2.0 technologies critical knowledge no longer languishes in organizational silos, but it become a dynamic asset that grows organically as anyone grab it, add to it and use it for different aims. Increasingly, employees are using these new web-based applications to collaborate and form ad hoc communities which span organizational boundaries. Closed, hierarchical workplaces, characterized by tight employment relationships are being transformed into self-organized, distributed and collaborative human capital network, that draw knowledge from both within and outside the firms. By harnessing synergies among users, these tools may help organizations compete globally and reach enormous competitive advantage.

Clearly, Internet and online collaborative tools may also contribute to foster innovation as collaborative output among globally distributed collaborators [Tapscott and Williams, 2006]. Internet had opened up access to talent market throughout the world. Numerous companies like IBM and Eli Lilly have begun to experiment with the new concept of open innovation, leveraging one another's innovation assets (even competitors), such as products, intellectual property and people [Huston and Sakkab, 2006]. The shift to Open Innovation models has been recognized as a major change in the way companies and other actors involved in the innovation value chain create and manage innovation. Open Innovation is defined as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation and to expand the market for the external use of innovation respectively" [Chesbrough, 2003, 2006]. Put differently, the central idea of Open Innovation is that in a world consisting of widely distributed knowledge, organizations cannot rely entirely on their own research activities and skills, but they should exploit external knowledge and competencies and find ways to profit from internal inventions or ideas that they cannot or do not want to exploit internally. In the Open Innovation paradigm, market-based mechanisms to capture external knowledge or to valorize internal ideas such as acquisition of Intellectual property rights, spin-offs and new venture creation are mixed with non-market value creation mechanisms based on collaboration among companies, R&D centers, independent problem solvers and even final users [Benkler, 2011; von Hippel, 2005]. Collaboration brings many benefits to members of innovative communities including sharing of R&D expenses and risk and free access to diverse know-how, ideas and skills developed by communities of practices.

On the internet, several applications able to support Open Innovation exist. One of the most famous is InnoCentive's Challenge Platform (www.innocentive.com). It is an open innovation company that enables organizations to solve their unsolved R&D problems by connecting them to diverse and numerous sources of innovation including employees, customers, partners, competitors and anyone is interested. It gives cash awards for the best solutions to solvers who meet the challenge criteria. In other words, it is able to match demand and offer of innovation solutions by using the web-based platform. InnoCentive has posted more than 1,300 challenges to its *global solver community*. InnoCentive currently enables challenges in a wide variety of disciplines, including business and entrepreneurship, chemistry, computer/information technology, engineering and design, food and agriculture, life sciences, math and statistics, and physical sciences. InnoCentive's solver community now consists of nearly a quarter-million creative and talented individuals from more than 200 countries, which collaborate to find the right solution for complex problems.

Additionally, organizations are, ever more, developing websites and organize events to support an open and collaborative innovation approach, involving employees, customers, stakeholders and anyone wants to collaborate to the realization and implementation of innovations. Since 2011, for instance, IBM organizes the IBM Innovation Jam event. It is an online brainstorming session that involves IBM employees, customers, partners, consultants and stakeholders for few days to promote innovation. The basic idea is to bring different minds and different perspectives together to discover new solutions to long-standing problems. IBM's Jams and other Web 2.0 collaborative mediums are opening up tremendous possibilities for open and collaborative innovation, that is a new ways of working across industries, disciplines, and national borders.

Another important initiative for supporting collaborative innovation processes was proposed by Dell in 2007, namely Dell IdeaStorm. The latter is a website allows organization "to gauge which ideas are most important and most relevant to" the public. It is an online forum where online users can suggest new business ideas, vote for their favourite submissions and interact with Dell. The site is so popular that other companies (such as Canonical, an open source advocate) are copying the concept, such as Starbucks, RadioShack, Canonical Ltd. By using these websites, organizations, not only, can involve customers and others stakeholders in their innovation processes, but can also gather important information about customer needs. In this way, organizations, indeed, are able to create stronger relationship with their clients, because they feel listened and part of the company.

As already mention, Web 2.0 applications have presented businesses with new challenges, but also new opportunities for getting and staying in touch with their customers, learning about their needs, exploiting their opinions and ideas, as well as interacting with them in a more direct and personalized way. This new kind of Internet-based tools has shaped and is still determining a new class of consumers. Indeed, the claim that “the customer is the king” has always sounded hollow, but now the digital marketplace has made it true. Web 2.0 has affected the power structure in the market place, causing a substantial migration of market power from producers and sellers towards customers. This happens because mainly nowadays’ customers can access to a previously unknown quantity of information and knowledge. Indeed, clients’ decisions and opinions about the products and services are not based exclusively on information makes available by company through traditional mass media or its website, but they are increasingly based on inputs provided by others users or parties not controlled by producers (peer reviews, referrals, blogs, forums etc.). In particular, organizations are even more exploiting the power of social media to build and develop more interactive and direct relationships over time with their customers. As social media is becoming the first channel through which customers learn about a brand, many companies are, of course, developing a presence within customer networks such as Facebook, Twitter, and YouTube. By using Social Media, companies have found a new way to be tightly connected, explore and exploit their ideas and needs and offer more and more personalized products and/or services. A new wave of digital advertising services and products offer brands the ability to go beyond their existing communities. Indeed, as emerged from Nielsen findings [2011] 60% of people who use three or more digital means of research for product purchases learned about a specific brand or retailer from a social networking site. And, 48% of these consumers responded to a retailer's offer posted on Facebook or Twitter. Thus, new channels and media have been developed and organizations have to quickly learn to exploit them as marketing tools if they want to compete and survive. Increasingly, consumers are co-innovating and co-producing the products that they consume as well. The gap between producers and consumers is blurring. A new kind of customer is born: the *prosumers*. It indicate increasing engagement of consumers into production processes. Tapscott and Williams [2006] claimed that the most active users form their own online communities, where they share information about products, collaborate on customized project and provide tips and suggestions. Therefore, competitive and smart companies will bring customers into their business webs and give them a lead role in developing new products and services. This means that organizations

Web 2.0 has transformed and is still transforming how businesses are managed. The least common multiple of these stories is the increasing involvement of employees, customers, suppliers, partners and stakeholders in various and different organizational processes through web-based technologies. The basic idea is that Web-based technologies allow harnessing collective output, not only of the entire workforce, but of the whole network of external parties on a scale never seen before. In nutshell, collective intelligence can be defined as the ability of groups to reach outstanding performances than each of its members can [Heylighen, 1999]. The lesson is: organizations that are able to effectively adopt and exploit Web 2.0 technologies will give themselves an enormous competitive advantages and let themselves to work globally. Companies has to open themselves up to ideas from outside their boundaries. They have to, not only to think globally, but they have to act globally to effectively tap a global talent pool.

Internet-based technologies can support different organizational processes, but in this work I focus on online distributed deliberation and decision making processes. In particular, in the next Chapter, I will explain how Web 2.0 tools, by harnessing Collective Intelligence, can foster online distributed deliberation process. Moreover, I will put emphasis on different characteristics of current web-based technologies explaining their strengthens and weaknesses with regards their ability to support the mentioned organizational processes.

Chapter 2
Web-enabled collective intelligence for supporting distributed deliberation process

2.1 Introduction

In the previous Chapter, I discuss on how Web 2.0 technologies have deeply permeated our real lives, radically modifying the way people interact, communicate, search and exchange knowledge and create collaboratively collective outputs. In this Chapter, I focus on the power of Web 2.0 to harness Collective Intelligence [O'Reilly, 2005; Malone and Klein, 2007; Malone *et al.,* 2010].

Web 2.0 tools, by letting wide amount of knowledgeable and interested individuals to freely communicate, interact and generate contents in self-organized and loosely coordinated way, has rapidly created new opportunities and forms of Collective Intelligence [O'Reilly, 2005; Malone *et al.*, 2010]. Collective Intelligence is based on the idea that large groups of individuals are remarkably intelligent and they are able to come up with decisions or solutions to a problem in a better way than each of its members can [Heylighen, 1999; Levy, 1997]. Even when most part of people within a group are not especially will-informed or rational, the group may still reach a collectively wise decision. This is a very surprising, since that human beings are not able to make optimal decisions because of their *bounded rationality* [Simon, 1972] However, under the right conditions, when our imperfect judgements aggregate, our collective intelligence could be often excellent. Although Collective Intelligence is an ancient phenomenon, new web-based collaborative technologies are allowing vast amount of people over the world to work together in a synergic and cumulative ways that were never before possible in the history of humanity. Examples of new flourishing forms on Internet are: Wikipedia (millions of volunteers around the world participate in writing the world's largest encyclopaedia), Google (it uses the knowledge millions of people have stored in the World Wide Web to provide remarkably useful answers to users' questions), Linux (hundreds and hundreds of individuals constantly use, change and improve its design through the availability of its source code). These successful stories in turn have induced many researchers and practitioners to think that it is possible to harness this new forms of Collective Intelligent over Internet for a number of different organizational tasks like collective Knowledge Management [Zettsu and Kiyoki, 2006], collective prediction [Sunstein, 2006], collective deliberation [Klein, Cioffi and Malone, 2007], collective problem solving [Iandoli *et al.*, 2009].

This research focuses on collective deliberation processes supported by Web 2.0 tools able to enable Collective Intelligence. The basic idea is to exploit Collective Intelligence of Web users as basis for supporting effective deliberation processes. Moreover, strengthens and weaknesses of current Internet-based technologies will be assessed respect their ability to support successful deliberation and decision making processes.

2.2 Using collective intelligence to make better decision

The human brain is an incredible instrument that has evolved over thousands of years to allow us to survive and prosper in many different conditions. Notwithstanding, our evolved decision heuristics have certain limitations, which have been extensively studied over the last few decades, in particular by researchers in the field of behavioural economics [Simon, 1972; 1982; 1991]. The way in which our brains are biased may not be well suited to support deliberation processes in current economic environments characterized by turbulence and hyper-competitiveness. Fast-paced world of business requires organizations increasing short responses time, more accurate decisions and a greater exploration of potential opportunities. In order to face this environmental complexity, in the last decades, many organizational decisions migrated from individual to distributed decisions based on the contributions offered by large, diverse groups of individuals within a firm or even from external firms [Shim *et al.* 2002]. The good news is that, thanks to Web 2.0 collaborative technologies, organizations can now draw together wide amount of diverse knowledge sources and competent individuals on a greater scale than ever before. Clearly, the role of web-based collaborative tools is not to replace mankind, but to promote the constructions of intelligent communities in which our social and cognitive potential can be mutually developed and enhanced [Levy, 1997].

The increasing use of wikis, prediction markets, social networks, forums and the like to support collaborative and distributed deliberation and decision making processes constitutes an important organizational paradigm shift. Indeed, Internet seems to offer the right and effective solution to support efficiently and effectively deliberation processes. Indeed, the advent of Web 2.0 has given rise to many new and enriched applications of existing technologies able to promote more consistent and well-supported decision making by enabling a larger number of users to participate and, thus, promoting a broader exploration of the solution space. In particular, new applications have made feasible for organizations to put together knowledgeable and interested individuals geographically dispersed with diverse skills in a cheap and efficient way [Cramton, 2001], without time and space constraints. Current web based tools which could be used to foster a pervasive participation are innumerable. Although the most common web-based tools (blogs, wikis, social networks) are noticeably basic compared to group decision support systems, they allow large groups of users to achieve outstanding results in knowledge sharing and accumulation. Numerous researches have proved that they foster, by reducing cost of participation, wide voluntary contributions which in turn can lead to remarkably powerful emergent phenomena, that include:

- *Idea synergy:* the ability for users to share their creations can enable a synergistic explosion of creativity, since people often develop new ideas by forming novel combinations and extensions of ideas that have been generated by others [Tapscott and Williams, 2006].

- *The long tail:* social computing systems enable access to a much greater diversity of ideas and allow to "small voice" to have a significant impact [Sunstein, 2006].

- *Many eyes:* social computing effort can produce remarkably high-quality results by virtue of the fact there are multiple independent verifications [Linus' law] [Raymond, 2001; Sunstein, 2006].

- *Collective Intelligence:* large groups of independent, motivated and competent individuals can collectively make better judgments than those produce by its smartest member [Surowiecki, 2005].

In accordance to this, it is now possible to support the synergistic and cumulative channelling of the vast human and technical resources now available on Internet and to exploit it for enabling collective approaches for making well-supported and accurate decisions.

Clearly, the concept of Collective Intelligent is not so new, but it is always existed Indeed, for instance, families, companies and countries are all groups of individual doing things that at least sometimes are intelligent. Beehives and ant colonies are examples of groups of insects doing things like finding food sources that are intelligent. The only real difference is that, nowadays, it is possible to exploit the potentialities of these technologies to harness the Collective Intelligence on a very large scale that was completely impossible few years ago. The idea behind Collective Intelligence is that a large group of individuals can collectively make better judgments than those produced by the single individuals that compose it. Often group's performances exceed also the ones reached by experts, as their collective judgment cancels out the biases and gaps of each member. So, intelligent behaviour emerge from the synergy of individuals in a group [Heylighen, 1999].

The power of Collective Intelligence for supporting deliberation processes depend also on the ability to exploit the diversity. Diversity is very important because it ensures that the group has a wide range of information. Basically, if a group consists of nearly identical people, it is unlike to be wise, because the group will not know more than individuals of whom it is composed. Raymond [2001] stated "*given enough eyeballs, all bugs are shallow*"; this is the *mantra* of Open source movements and it indicates the greater ability of large groups to find and fix eventually bugs. Larger groups are able to make better decisions because there are diverse point of views, competences and knowledge which are crucial to better understanding and analysis of the problems, as well as a greater exploration of solution space. Another important advantages deriving from the utilization of large groups for supporting deliberation and decision making processes is that, in this way, it is possible to involve people that works in different fields. Often, there are people out there who can help organizations to solve problems, and, moreover those individuals are not necessarily where someone might expect them to be. Many times problem solutions come from industries, fields or area which are not even thinkable. Diverse competencies and expertise can contribute to a better understanding of the problem [Pelled *et al.*, 1999], as well as can allow a richer and more complete problem analysis and evaluation [Page, 2008] and mitigate self-serving bias and belief perseverance [Bonabeau, 2009]. The importance of diversity was proved by Page [2008] through a set of experiments. The result showed that the diversity is a crucial condition to make a group more able to solve a problem and that only the intelligence is not enough because it does not ensure that the problem will be seen from different views as well. Adding less expert people, but with different competencies, the performance will be better than one reached by a group of savvy individuals. According to Page, this happens because intelligent people are similar and they know approximately the same things. Too homogenous groups have more difficulties to learn and update their knowledge, because their members bring too little new information. If new members are introduced, even if less expert and capable, generally the group becomes smarter and should increase the productivity [Pelled *et al.,* 1999; Vennix, 1996]. However the same diversity may hamper collaboration as posited by the *Absorptive capacity* concept proposed by Cohen and Levinthal [1990]. Therefore, not all collaborations have been successful [Barron, 2003], because there are situations where the diversity of knowledge can hinder effectiveness or some groups may overemphasize cohesion and neglect critical thinking, hampering a proper analysis of alternative solutions [Janis, 1982]. The lesson here is that organizations that make use of collective approach to support decision making processes have to find the right balance between diversity and expertise.

The four major causes of failure of groups involved in decision making process are [Sunstein, 2006]:

- *Hidden profiles:* groups may not be able to reach the necessary outcome because some group members do not elicit all the relevant information held because of the presence of social pressures (low information disclosure). Indeed, in all groups involved in decision making processes there are two kinds of information, that is *common information* available to all participants and *private information* held by a single member. When a hidden profile is present only the common information will be used and it will support a sub-optimal alternative. On the contrary, if the each group member disclosed both common and private information and evaluated it in an unbiased way, it would prefer a different, superior alternative. One of the leading causes is that groups disproportionately discuss common information as opposed to the group members' private information [Stasser and Stewart, 1992]. Other factors include information overload (too much information for individuals to remember) and biased recall that favours the alternative that each member's pre-discussion information indicates as the best alternative [Stasser and Titus, 2003].

- *Error Amplification:* social dynamics mostly work in favour of the group error risk. According to Condorcet Theory, groups are error-prone if most of their members are likely to blunder. In this case, the probability of a correct answer, by a majority of the group, decreases toward zero as the size of the group increases.

- *Cascade effects:* When group members express their opinions in a sequential way and when the majority of them reveal initially their ideas in supporting of a certain view, those who follow would feel pressure to have to make the same choice. This problem could be much higher when the follower is indecisive. A similar effect can be observed because of the reputational concerns when people support a view, not because they believe in it, but just because they do not want to look foolish in front of others. The result would therefore be a premature and fake convergence of ideas. The main aspect of cascade effect is that, at a certain moment, people decide to not consider own information and knowledge and begin to follow the others' behaviour. Gladwell [2000] proposed another explanation of why *cascade effect* occurs. He claimed that such phenomenon arises because of the presence of some influent people. These influent individuals are experts. Therefore, the cascade effect is not determined by a set of people that imitate each other, but rather individuals are affected by social relationship and pressures

- *Group Polarization:* is the tendency of people to become more extreme in their thinking following the group discussion [Isenberg, 1986]. Overconfidence that may rise as result of being supported by the group can reinforce extremist view as well. There are two main causes, extensively investigated, for group polarization, namely *social comparison* and *persuasive arguments*. According to Social Comparison Theory, group polarization occurs because people are motivated to present themselves in a socially desirable light during discussion [Brown, 1965; Sunstein, 2002]. Social influences may take a crucial role as well. People continually compare their opinions with others' ones. The mechanisms that facilitate this phenomenon are *one-upmanship* and *pluralistic balance. One-upmanship* is the tendency of people to try to outdo each other in the socially valued direction [Fromkin, 1970]. *Pluralistic balance* is the desire of people to achieve a compromise between their preference and the positions of others. The second explanation, emphasizing the role of *persuasive arguments*, is based on the idea that any individual's position is function of which arguments presented within the groups seem convincing [Sunstein, 2002]. The choice therefore moves towards the most persuasive position defended by the group.

On the contrary, the following two conditions seem to support group to outperform even their best members [Iandoli *et al.*, 2009]:

- The correct solution is widely supported by the group members before starting deliberation. In the extreme case, at least one of the group members knows the right solution and is able to persuade and convince the rest of the group.
- Group members believe that the problem has a clear, correct and well-known solution. This happens when the problem in hand is a so-called *eureka* question or when a self-evident superior solution exists

The above mentioned main causes of deliberation and decision making failure have been investigated mainly through experiments with small, closed and physically collocated groups, but it is possible to think that these problems could also appear in large-group collaborating through Internet. In any case, the exploitation of collective approaches enabled by web-based technologies could be seen as possible solutions for organizations to better deal with environmental complexity which require increasingly companies crucial and accurate decision in short response time. Nowadays, responsiveness and reaction speedy are important elements that could ensure the survival and success to the companies [Bonabeau, 2009].

In the next paragraph, online technologies will be evaluated with respect their ability to effectively support collective deliberation processes.

2.3 Current web-based technologies for supporting collective deliberation processes

Organizations routinely make decisions that require the involvement of a collectivity [Sankaran and Bui, 2008]. Moreover, collocated meetings are very expensive, limit the breadth of interaction and the diversity of knowledge and are prone to serious dysfunction such as polarization, hidden profile and cascade effect [Sunstein, 2006]. Current web-based tools could represent a straightforward technique to enable a cheap and easy way for collecting a wide amount of knowledgeable and skilled people, ensuring a certain degree of diversity of information and a wider exploration of solution space. Therefore, in order to better analyze the strengthens and the limitations of these tools in supporting deliberation and decision making processes, it is helpful introduce them dividing them in three categories: Sharing tools, Funnelling tools and Argumentation tools [de Moor and Aakhus, 2006; Klein, Cioffi and Malone, 2007].

2.3.1 Sharing tools

The Internet owes mainly of its success as collaborative platform to this category of tools. Indeed, by far most commonly used web-based tools are wikis, forums, blogs, social networks are the so-called *sharing tools* [Josan, Isamil and Boyd, 2007].

A wiki is a set of web-pages that can be easily edited by anyone who is allowed access [Ebersbach *et al.,* 2006]. Anyone can add a new article and/or edit and revise existing one. Wikipedia's popular success has allowed to fully and widely understand the concept of the wiki as a collaborative tool that facilitate the production of a group work. The main strengthens of wikis in supporting work group are the ease of use, even playfulness, their extreme flexibility and open access [Ebersbach *et al.,* 2006; Lamb, 2004]. A weakness of wikis is that they capture, by controversial topics, the *least-common-denominator consensus* between many authors. Put differently, any non-consensus element presumably will be edited out by those that do not agree with it.

Blogs are the most common web-based tools. It lets people to publish content continuously. It refers to a simple web page where people can entry opinions and facts in a journal style, arranged in a chronologically order. One of the most famous blog is Slashdot.org. As the blogs are time-centric tool [Klein, 2010], where the content organization is based on *when* a post is created, they face some shortcomings from the perspective of enabling collective deliberation [Sunstein, 2006]. The content in time-centric tools is typically scattered, so it is hard and time-consuming to be able to find all the contributions about a topic of interest. Additionally, this fosters unsystematic coverage of the topic as it is no simple quickly understand which areas are well-covered and which need an in-depth examination. It is notorious that content captured through these tools is voluminous, redundant and overwhelming. This could imply the occurring of the phenomenon of *low signal-to-noise ratio.* The latter makes difficult to identify the novel contributions that should inspire people to generate creative new ideas.

Forum is an online discussion site where people can hold conversations in the form of posted messages. They differ from chat rooms because messages are at least temporarily archived. Moreover, depending on the access level of a user or the forum set-up, a posted message might need to be approved by a moderator before it becomes visible. With the developed of World Wide Web, forums had a widespread diffusion by attracting people who do not have technical skilled. Forums present the same shortcomings of the other kind of time-centric tools, such as blogs and chats. Additionally, forum discussions do not scale well because it is very difficult for later-comers to make sense of a conversation already started by other participants [Gurkan *et al.,* 2010].

In nutshell, sharing tools have remarkably successful at enabling a global explosion of knowledge sharing and accumulation, but they have to face numerous shortcomings when applied for supporting deliberation and decision making processes around complex problems. First, sharing technologies do not let to identify a group's consensus. Their inability depends mainly on the way which content is captured, which is often unsystematic, redundant and highly variable quality. Moreover, such tools do not support critical thinking and valid argumentation; therefore contributions are often bias-rather than evidence- or logic-based [Iandoli *et al.,* 2009]. Sharing tools are not able to effectively mediate controversial discussions and the presence of loose-structure cause the so-called phenomena "flame wars" or "edit wars". Users repeatedly re-edit or undo or reverse the prior user's edits in an attempt to make their own preferred version of a page visible. Edit wars could be also the result of a dispute on a trivial issue such as the nationality of Copernicus or of Freddie mercury. Therefore, unproductive debates could take place also in expected uncontroversial ones. Flaming is a similar event, but it occurs in online forums. Usually, flame wars reduce the signal-to-noise ratio discouraging people to stay in the online community.

2.3.2 Funnelling tools

Funnelling tools are able to support aggregation of information and individualization of most widely held view. This class of web-based technology includes e-voting and information aggregation markets (IAMs). E-voting systems apply simply election principle. They can be successful when there are market incentives and a structured voting process. Numerous studies proved that IAMs are effective at aggregating information provided by a large group of independent and diverse individuals. Participants have to bet on their supposed correct answer and receive a financial reward if the bet is correct. Perhaps the best known prediction market among economist is the Iowa Electronic Market, run by the University of Iowa, which produces accurate estimations about American elections. There is evidence that such markets can help to produce forecast of event outcomes with lower prediction error than conventional forecasting methods. In particular, several researches emphasize the potential of prediction markets to improve decisions [Hanson, 1999; Snowberg *et al.,* 2007]. The range of applications is virtually limitless, such as helping business make better investment decisions or helping government make better fiscal or monetary policy decisions. Additionally, their accuracy has already encouraged many private organization to use them, such as Google [Cowgill, 2005], Yahoo [Cowgill *et al.*, 2008], IBM, France Telecom, Hewlett Packard [Wolfers and Zitzewitz, 2004], Intel, Microsoft. The success of prediction markets depends on their design and implementation. Some key design issues include the existence of market incentives, which motivate people to search for rational choices, and of simplicity of problems, that is if it is possible to define a set of known and limited possible alternative solutions. Put differently, prediction markets cannot be used to deliberate on complex problems, where it is not possible to define *a priori* a set of solutions. Moreover, others crucial elements able to guarantee unbiased outcome are the independence of individuals and the lack of interaction.

The main weakness of prediction market is that they do not support online users to develop a shared understanding of the problems and to propose further alternatives. The options are provided before interaction. These tools do not make visible how users search, aggregate and create new knowledge.

2.3.3 Argumentation tools

Online argumentation tools make use of the argument theory to mediate and represent debates. Argumentation theory deals with how humans should and do reach conclusions through reasoning. There are differences in argumentation theory on how to define an argument. The basic idea is that an argument is a set of statements, made up of three elements, such as a conclusion, a set of premises and an inference from the premise to conclusion. An argument can be supported or attacked by other arguments.

Argument diagramming is often recognized as a powerful methods to analyze and evaluate arguments [van den Braak, 2006], as well as to support correct reasoning. Usually, an argument diagram is a “box and arrow” representation, with boxes corresponding to propositions and arrows displaying the semantic relationships among them [van Gelder, 2002]. A range of mapping approaches, then translated in software tools, were developed, but all enable to decompose an argument into its constituent components, letting to represent content in a concise and easy to follow manner and making the logic behind the reasoning more evident and visible. Different type of argument mapping techniques are presented.

Concept mapping (Figure 1) was developed by Novak in 1972 on the basis of Ausubel’ theory. This theory claimed that learning takes place when new concepts are connected to what is already known. Concept map, therefore, lets users to represent knowledge as a graph, where concepts are nodes linking through words that indicate relationship thus forming a proposition. Usually, concepts are represented in a hierarchical order, from most general and inclusive concepts at the top the least inclusive and specific ones at the bottom. This type of argumentation tools are widely used in the evaluation of students’ learning in the school system [Novak and Gowin, 1984]. An example of tool that apply these argument mapping technique is *Cmap* Tools is an educational argumentation tool. Different studies [Novak and Gowin, 1984; Canas and Novak, 2008; Marriot and Torres, 2008] showed that CmapTool is an effective tool for supporting learning and deep understanding of a topic. Indeed, it is often used as an artefact through which students can collaborate and discussed about a specific topic, becoming a starting point of the learning [Canas and Novak, 2008].

Argument and Evidence Mapping (Figure 2) was proposed by Wingmore [1990] as technique able to support teaching and analysis of court case. The key elements of an argument map are *Claims, Evidences and Premises* which are connected through supporting/challenging relations. Therefore, in an argument map, the functional relationships among claims are made wholly explicit using graphical or other non-verbal techniques [van Gelder, 2003]. The aim is to visually represent the structure of an argument, in particular how evidence is being used in order to clarify the status of the debate. Argument maps have been used for supporting different tasks, such as teaching and deliberation processes around complex problems.

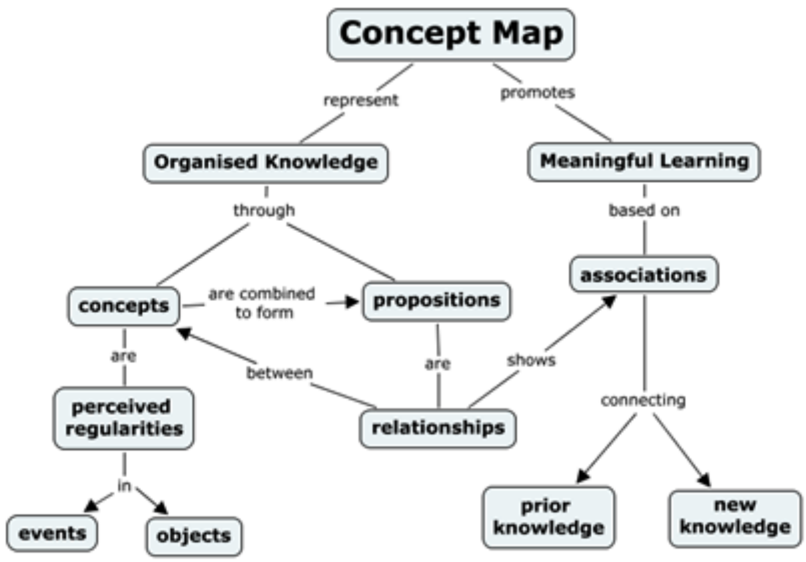


Figure 1. Concept Map created with Cmap tool [Okada *et al.,* 2007]

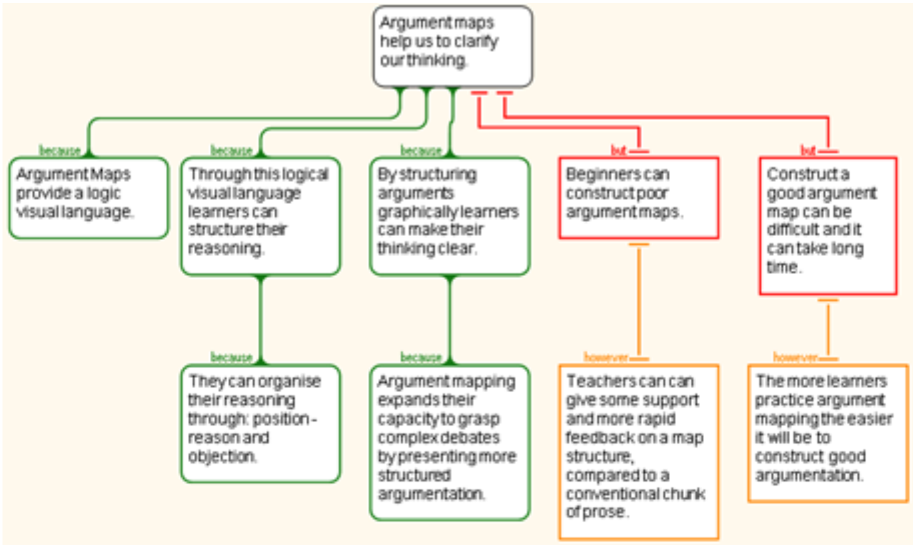


Figure 2. Argument Map created with Rationale tool [Okada *et al.,* 2007]

Issue mapping (Figure 3) allows users to represent argument by using Issue Based Information System (IBIS) format which was proposed by Rittel in 1970s. IBIS scheme was created in order to support users in tackling wicked problems, by helping groups to represent a debate as a visual map composed of a set of *issues* to be answered, *positions* (or ideas) as alternative solutions to issues and supportive or challenging *arguments* about proposed ideas. The three key elements are connected through labelled links such as *supports to, objects-to, suggested by, replaces.* Conklin [1988] translated IBIS format in a hypertext data model supporting dialogue visualization.

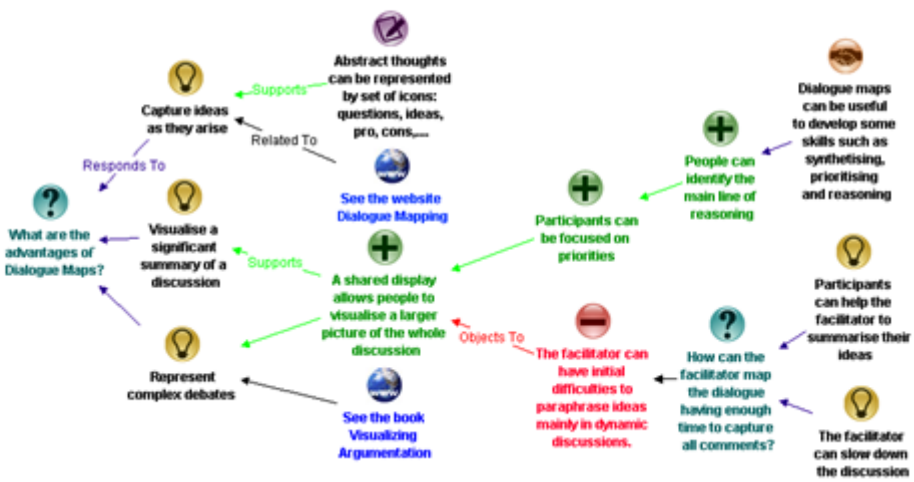


Figure 3. Issue Map created with Compendium tool [Okada *et al.,* 2007]

Argumentation tools allow users to represent complex reasoning in a concise, easy to follow, clear and unambiguous way, making the logic behind an analysis more evident. This fosters users to identify relevant information. The main feature of argument tools is to encourage careful critical thinking [Buckingham Shum *et al.*, 2006; van Gelder, 2007], by implicitly requiring that users express the evidence and logic in favour of the options they prefer. Moreover, the arguments are captured in a compact form that makes easy to understand what has been discussed and, if desired, add contributions to it without needless duplication. In this way they are expected to enable increased synergy across group members as well as non-redundant knowledge accumulation over time. Such tools are supposed to be particularly suited to foster deliberation and decision making processes around complex problems as they allow users to represent contentious and/or competing point of views in coherent structures made up of alternative positions on an issue at stake with their associated chains of pros and cons arguments. This reduces the risk of group polarization phenomenon. Additionally, as each contribution appears just once, it radically increases the signal-to-noise ratio. In general, by providing a logical-based debate representation, and by encouraging evidence-based reasoning and critical thinking, should significantly reduce the prevalence of some critical pitfalls that usually lead to deliberation failures in small scale groups and promote a more well-supported decision making.

Notwithstanding, argumentation tools also face some important shortcomings. First, argument maps do not scale well: when the number of users increases the construction of proper collective maps appear to not be self-sustainable and self-organized and requires intensive moderation [Gürkan *et al.*, 2010]. The assumption is that, by prioritizing the formal representation of contents generated by users, researchers and developers have neglected other important social and communication aspects which are very important in fostering communication and make participation more engaged. This has raised concerns on the capability of argumentation to act as effective mediator and facilitator of interaction. Indeed, a central problem is the presence of communication formats too constraining and intrusive that disrupt the natural flow of free conversations. In turn, the use of formalism too strict entails a steep learning curve: a proficient use of argument mapping tools requires a certain amount of regular practice and training [Twardy, 2004].

Scaling problems, ineffective mediation, need for practice and training imply more intense cognitive effort for users willing to participate to an argument-based conversation than it is required by current conversational technologies.

2.4 Conclusions

Increasingly, organizations have to cope with complex problems. This is consequence of rising of environmental complexity. In literature, there is evidence that a right way to face with such complexity is to exploit the potentialities of Web 2.0 in harnessing Collective Intelligence [Bonabeau, 2009].

In the previous paragraphs, a short review of the main collaborative technologies able to foster Collective Intelligence and, thus, deliberation and decision making processes around wicked problems has been presented. In literature, there are evidence that to support efficient and effective decision making it is important to involve large group of independent and competent individuals with diverse skills and knowledge and no past experience. Sharing tools have showed to be successful to gather very large groups of individuals unless the diversity leads to controversial situations and therefore unproductive debates through the presence of high level of structure. Moreover, sharing tools are often criticized on how knowledge is captured and represented. Indeed, they tend to produce redundant and overwhelming content at the presence of large groups. Argumentation tools are supposed to handle better massive exchange of knowledge, reducing redundancy thanks to a compact representation of it. Funnelling tools are able to support an effective aggregation of information and to hold the widely support solution, but do not make visible the reasoning behind that “bet” and how new knowledge has been created. One of the strengthens of argumentation tools is exactly the capacity to make the logic behind a decision visible.

Though there is evidence that argumentation tools could be the right tool for mediating online large deliberation processes on complex problems, it is not flawless. First, the presence of participation and communication formalisms implies a steeper learning curve with respect to the other online tools. Second, the structure of argumentation considers social cues as irrelevant thus impeding social communications. Notwithstanding, social communication has been found to be influential in creating trust [Chidambaram, 1996] which in turn has consequences on team effectiveness. Moreover, by prioritizing the formal representation of contents generated by users over the temporal flow and turn-taking structure typical of conversations, make this technology too constraining in absence of clear and immediate visible benefits perceived by users. This has entailed an objectification and formalization of conversation around the knowledge map, as well as the loss of a range of meta-information about participants and the interaction process through which the content is generated. The loss of this meta-information hinders free interaction and makes conversation less efficient [Clark and Brennan, 1991].

In the Chapter II, a more deepened analysis of argumentation tools will be presented in order to better understand and evaluate the strengthens and weaknesses of such tools for effectively supporting deliberation and decision making processes.

Chapter 3
Computer supported argument visualization

3.1 Introduction

As emerged in the previous chapter, Internet would be a straightforward means for allowing a wide amount of geographically dispersed individuals to deliberate and make collective decisions. The ways people can collaborate through web 2.0 are innumerable given the broad range of online tools and applications available. Although, traditional online tools, such as blogs, forums and wikis have showed a remarkable success in enabling efficient and effective knowledge sharing and accumulation on large scale, they appear to be less supportive of knowledge organization and re-use [Iandoli *et al.*, 2009]. In order to tackle this problem, numerous alternatives have been proposed to provide online communities with suitable tools and mechanisms for supporting deliberation processes.

Chapter I ended with the conclusion that argumentation technologies could be the desired method for mediating online communities' deliberations processes. Therefore, in this chapter, a more detailed review and analysis on argumentation tools is presented in order to better understand their virtues and shortcomings.

3.2 Argumentation theory: a short introduction

The *ability to argue* is an essential human skill involved in a wide variety of professional and daily life situations. Argumentation concerns with how conclusion can be reached from a set of premises through the application of a reasoning. According to argumentation approach, every opinion can be broken into different elements, such as the conclusion that it makes and the premises that lead to that conclusion. In nutshell, it is the process by which people reach a conclusion through a logical reasoning [Carr, 1999; Toulmin, 1958]. People regularly engage in argumentative practices, for instance, when they advance in defence of certain assertions or actions and when they react to opinions put forward by others. Real life cases of exercise of argumentation approaches are, for instance, when an employ tries to convince his boss to invest money in a new project, or when a politician argues for a new national monetary policy or when a lawyer has to rebut an indictment to defense his client.

Argumentation can be defined as

> *a verbal, social and rational activity aimed at increasing (or decreasing) the acceptability of a controversial standpoint for the listener or reader, by advancing a constellation of propositions justifying or refuting the proposition expressed in the position* [van Eermeren *et al.*, 1996].

In detail, it is *verbal* activity because it is normally conducted in an ordinary language. An individual uses certain sentences to reply to questions or rejection, to assert something or to rebut a claim put forward by others. As other verbal activities, argumentation may well be come with the use of nonverbal means of communication, such as facial and body expressions and gestures, but not to the extent that the verbal expressions are completely replaced by the nonverbal ones. Argumentation is a *social* activity because usually it is directed at people that individuals try to convince about own ideas. Finally, argumentation is an activity of *reason.* Putting forward an argument means that the arguer attempts to show the rational of his or her position on the matter.

Since the time of the ancient Greek philosophers, and even earlier, in Chinese culture, many different theoretical and practical approaches to argumentation have been proposed, which vary on the basis of the type and number of elements through which is possible to scaffold an argument. Although, different approaches exist, they share some basic principles, such as both supporting and attacking claims should be token in account and claims should be well-grounded. In general, such argumentation approaches, by letting people to decompose opinions into their constituent elements, enable more evidence-based and coherent reasoning and make, in particular, a logic behind a reasoning more visible and evident [Buckingham Shum, 2006; Cho and Jonassen, 2002; van Gelder, 2003]. In other words, argumentation theory offers a formalism and a set of rules which may guide people to the creation of well-reasoned argument. Thus, they may be a powerful methods to support individuals to reason more effectively [van den Braak, 2006].

Different argumentation formalisms have been developed to support users in the construction and visualization of arguments. By introducing argumentation formalisms, such systems, hence, allows users to build graphical representation of the reasoning process underlies any type of discussion. As this task is laborious, many researchers and practitioners have developed different software tools as means for supporting discussion representation based on argumentation theory. Such technologies aid users to create, manipulate and review their arguments as well. These platforms are collectively referred to as Computer-Supported Argument Visualization (CSAV) technologies [Buckingham Shum, 2003].

In the following, I provide a brief description of two basic and well-known argumentation formalisms, such Toulmin's scheme [1958] and Issue Based Information System [IBIS, Kunz and Rittel, 1970; Rittel and Webber, 1973].

3.2.1 Toulmin's scheme

One of the most known argumentation formalism is that proposed by Toulmin in his book "*The Uses of Argument*" [1958]. Toulmin's original aim was to analyze as arguments work. In other words, he wanted developed a model through which it is possible to assess the validity of a logical reasoning. Toulmin believed that reasoning is less an activity of inference, involving the discovering of new ideas, and more a process of testing and shifting of already existing ideas. Toulmin believed that a good argument should be able to provide justifications for a claim. This, therefore, should ensure it stands up to criticism and earns a favourable verdict.

His analysis of the logical structure of an argument led him up to define a specific framework. This argument framework suggests that a statement is made up of six constituent elements that have different functions [Toulmin, 1958]:

- The *Datum*: is the facts, evidence or expert opinions that support individual's conclusion. The *Datum* is the basic premise on which the rest of the argument is built; it is the "truth" on which the claim is based.
- *Claim:* is the conclusion made in an argument and that will be argued. It can be meant as a statement that people ask the other person to accept.
- The *Warrant:* is the inference mechanism or the bridge that allow to connect the datum and the claim. In other words, it is used by individuals to justify why data is relevant to the claim. It does not necessarily have to be a causal rule, but its role is to foster reaching of conclusions through a logical step.
- *Backing:* is the set of information or credentials that support the warrant. Backings are used to establish the general conditions that strengthens the acceptability of the warrants so that the connections among data and claim will not be analyzed.
- *Qualifier:* set of statements that express the degree of force or certainty of the claim.
- *Rebuttals:* counter-arguments or set of statement that constitute exceptions or limitations to the validity of the claim.

Toulmin defined the process of constructing a scientific argument mainly as the process of using data, warrant and backings to convince the others of the validity and acceptability of a specific claim. Therefore, the strength of an argument depends on the presence or absence of these different structural elements. Therefore, stronger arguments contain more of these components than weaker arguments. In light of this classification, the statement may be represented as Figure 4. As it possible to evince from the figure, arguments are generally expressed with qualifiers and rebuttals rather than asserted as absolutes. This enables individuals' critical thinking skills and make visible to others the logic or the reasoning behind the claim. Toulmin proposed this graphical format for laying out the structure of an argument as means to analyze and assess the rationality and goodness of arguments. For these reasons, Toulmin framework has often been used as model of reference to evaluate the validity of arguments in numerous studies [Suthers, 2003; Gurkan *et al.*, 2010]. It was initially based on legal arguments, but it may be applied also in the field of rhetoric [Carr, 2003] and communication.

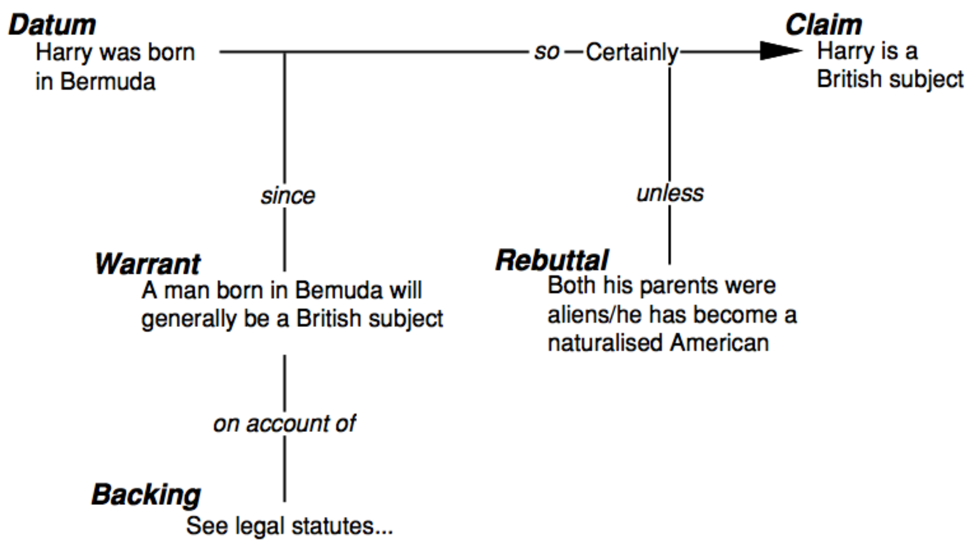


Figure 4. An example of Toulmin's formalism [Toulmin, 1958]

Toulmin's theory has had an enormous impact on many disciplines and it has found wide application in many argument-based computer systems (i.e. *Belvedere, Reason!Able*). As Toulmin's formalism is not easy for novices to understand and learn to use [Voss *et al.,* 1983; Voss, 2005], generally Toulmin-based platforms have try to simplify his theory to the point to make his approach a highly usable structure (i.e. by deleting explicit warrant, which are generally left implicit in everyday reasoning).

As already mentioned, an example of Toulmin-based platform is *Reason!Able* platform [van Gelder, 2003]. It is an argument diagramming tool that support an easy and quick construction and modification of argument representation [van Gelder, 2003]. Its key elements are: i. Positions (claim); ii. Reasons (datum and warrant); iii. Objections (rebuttals). This argument mapping tools was not designed to mediate collaborative discussion, but it has mainly been used as argumentation aid in educational setting and to support organizational deliberation process in face-to-face meeting with the presence of a facilitator and sponsor of the technology.

Another platform which applies loosely Toulmin's formalism is the *Belvedere* platform [Suthers and Weiner, 1995; Suthers, 1999; Suthers and Hundhausen, 2001]. Initially, *Belvedere* implemented completely Toulmin's formalism, but some studies demonstrated that students have difficulty to fully understand the meaning of the provided element, that interfering with the student's ability to communicate each other [Suthers, 1999]. This research findings led the *Belvedere*'s creators to simply the set of available primitives. Nowadays, Belvedere allows to represent arguments as graph where users' contributions are visualized as node and the links among nodes represent the relationships among contributions. There are not studies that confirm the improvement of the usability of this "reduced" formalism.

3.2.2 IBIS formalism

Another strand of argumentation technologies have their origin in the Issue Based Information Systems (IBIS) methodology. It was proposed to tackle the so-called *wicked problems,* and specifically wicked problems. Rittel and Webber [1973] defined "wicked" problems in contrast to "tame" problems. "Tame" problems are not necessarily trivial problems, but can be tackled with more confidence and it is clear when a solution has been reached. Wicked problems lack a single, agreed-upon formulation or well-developed plans of action, are unique and have no well-defined stopping rule, because there are only "better" and "worse", rather than right and wrong solutions. Closure is often forced by pragmatic constraints, such as managerial or political, rather than "rational scientific" principles [Rittel, 1972]. As such problems could not be solved by formal models or methodologies, an argumentative approach seemed more appropriate. Indeed, an open-ended, dialectic process of defining and debating issues in a collaborative way may represent a powerful method to discover the structure of the wicked problem. This need motivated and led to the development of IBIS as medium able to encourage the open deliberation of issue. As representational scheme (Figure 5), IBIS lets users to represent a debate as a visual map composed of a set of *Issues* to be answered, *Positions* (or ideas) as alternative solutions to issues and supportive or challenging *Arguments* about proposed ideas. The key elements can be connected each other through labelled links such as *supports to, objects-to, suggested by, replaces.* Issue can further sub-classified as:

- Factual Issue: "Is X the case?".
- Deontic Issue: "Shall X become the case?"
- Explanatory Issue: "Is X the cause for Y?"
- Instrumental Issue: "Is Y the right way to realize Y in this situation?"

The power of IBIS approach depends on its intrinsic features, that is it lets users to map complex thinking into structured analytic diagrams. By using IBIS platform, users can organize large amount of information and knowledge in a compact and easy to follow visual map. This type of formalism imposes a specific structure. This has two important implications. On one hand, the more specific an argumentation visualization technique is, the better it should support problem analysis, the easier it should be to make sense of the problem and solve it. On the other hand, the more strict and specific a formalism is, the more difficult and time-consuming is to learn to use. This is an important trade off that this type of technologies should try to face.

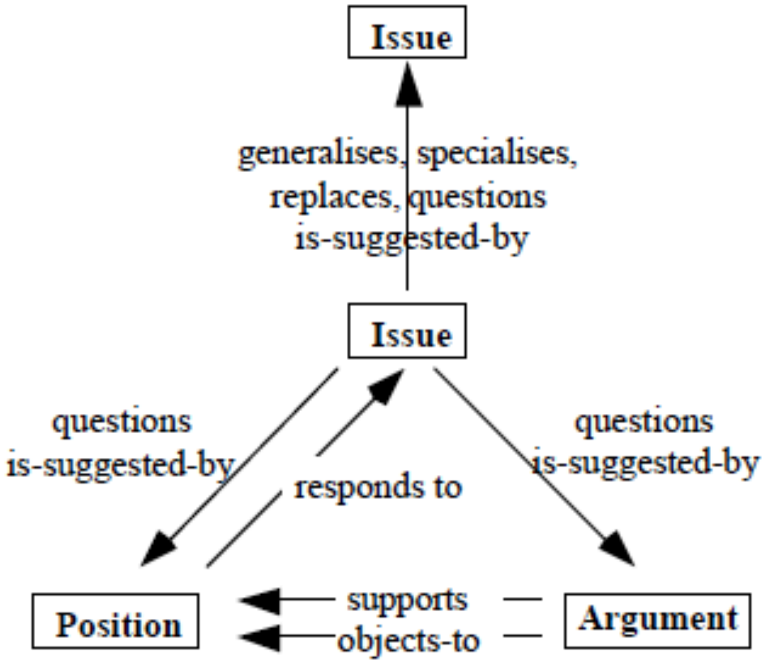


Figure 5. Basic IBIS structural units and links

gIBIS is an early computer-based implementation of IBIS approach [Conklin and Begeman, 1988]. The system was assessed as an organizational collaborative Knowledge Management tools. Empirical findings, though showed some limitations on the formalism itself, have proved the success of *gIBIS* among employees, both as collaborative tool and as a tool for annotating, structuring and recording ideas and knowledge.

Different tools that apply IBIS formalism exist, such as *QuestMap*, *Compendium*^{TM}, *Cope_it!, Carneades*, *Deliberatorium*. The applications of these systems are not limited to solve wicked problems, but they has been also used as educational tool for support scientific argumentation (*Compendium*^{TM}*, Cope_it!*), as deliberation and decision support system (Cope_it!) or to teach legal argumentation (*QuestMap*). Conklin [2003] reports some results about a study on the use of *QuestMap* tool in organizational setting. He noticed that the power of IBIS platform as annotation tool depends on its ability to organize, accumulate and store all information, knowledge and assumptions of users becoming an "organizational memory" and a point of reference for supporting further discussions about the faced issue. Additionally, Conklin observed that users found the platform useful only when they are become proficient with the formalism. Thus, as mentioned above, the main argumentation limitations, emerged from his study, regard the presence of a steep and long learning curve and the need for organization to have a "cheerleader" able to sponsor and to promote the use of the technology.

3.3 The rise of computer supported argument visualization

Argumentation can be defined as the ability to argue and defend a specific position. The point of argumentation is to influence other's attitudes by means of arguments. In accordance with this, human beings continually use their argumentation capabilities in everyday lives. Unfortunately, many people are not so able arguers [Khun, 1991; Tannen, 1998]. Kuhn has carefully documented the ways in which people fail to practice "good argumentation" in their own everyday activities. Her research reveals a number of concerns about human beings ability to argument properly and effectively. Two of the most critical Kuhn's worries are:

- People are typically unable to distinguish between argument and evidence needed to support it.
- People are not very good at using evidence to evaluate competing claims.

This gap motivated many educational and learning science researchers to investigated how computer technologies could support and foster the learning of argumentation in different fields, such as the law [Aleven and Ashley, 1997; Pinkwart *et al.,* 2006], science [Ranney and Schank, 1998; Suthers *et al.,* 2001], conversational argumentation [McAlister *et al.,* 2004; de Groot *et al.,* 2007], rhetoric [Carr, 2003]. As result of these researches many and diverse argumentation systems have been developed and implemented. Software that supports the construction of arguments, usually through visual representations called argument maps. It is important to underline that not all argumentation tools use the same representation format, but, surely, the most common is the graph style. This aspect will be discussed deeply in the next paragraph. this kind of activity is referred to as Computer Supported Argument Visualization (CSAV) platforms. Therefore, most common CSAV systems are able to combine and leverage the advantages deriving both from the use of argument mapping techniques and the inherent features of computer-based technologies (i.e. widespread adoption, speedy, superior availability as compared to human teachers, higher ability to store information etc.). In other words, argumentation systems lets users to create, edit, navigate and review argument maps.

An argument map can be defined as a visual representation of a reason in which the functional relationships among claims are made wholly explicit using graphical or other non-verbal techniques [van Gelder, 2003]. The main feature of argument maps is that, they allow users to present complex reasoning in an easy to follow, clear and unambiguous way. Moreover, by displaying knowledge visually through a spatial metaphor and by providing a logical rather than chronological knowledge organization, argument maps are helpful for key cognitive tasks such as sense making [Weick, 1995] and critical thinking [Buckingham Shum *et al.*, 2006; van Gelder, 2007]. Over time, researches have, in particular, focused on the benefits deriving from the use of argumentation technologies and the main empirical results show that explicit representations of evidence-based reasoning support critical thinking [Buckingham Shum *et al.*, 2006; van Gelder, 2007], encourage participants to clarify their thinking [Brna *et al.,* 2001] and to make it visible to others [Bell, 1997]. Additionally, according to van Gelder [2003] argument maps are better than prose to represent the structure of a reasoning and arguments for four main reasons:

- *Prose requires interpretation:* prose requires readers to lay out the relationships among the claims. This is not a simple work because each reader could come up with a different reasoning interpretation given different individuals' knowledge, skills and backgrounds.

- *Prose neglects representational resources:* prose makes little or no use of any kind of colour, shape or representational object to provide information about the structure of the reasoning. In reality, the brain can process large amount of information conveyed through visual representations by reducing cognitive effort [Donath *et al.*, 1999; Viegas and Donath, 1999; Dave *et al.*, 2004; Nguyen and Zhang, 2006; Suh *et al.*, 2008]. Argument map exploit this advantage making large use of colours and shapes to represents the different components of an arguments. While, in prose users has to interpret the claim and its context to understand its role in the argument.

- *Prose is sequential, argument are not:* this exacerbates the difficulty that a reader has in understanding a reasoning. Indeed, readers have mentally to reconstruct the non-sequential logical structure from the sequential sentential structure of the prose. While, argument maps present the whole reasoning, all at once, in its proper order.

- *Prose cannot visually display metaphor:* individuals can provide additional information, such as what the more important claim is or how stronger an objection is than others by using symbols and metaphor (i.e. size of users' contributions or spatial location etc.).

These advantages have aroused a wide and deep interest among both Computer-Supported Collaborative Learning (CSCL) and Computer-Supported Cooperative Work (CSCW) researchers and practitioners which led to the realization of large amount of different argumentation tools. As already mentioned, with regards CSCL field has paid much attention to ability of argumentation technologies to foster teaching of argumentation skills and on how students could benefit from them [Andriessen, 2006; Stengmann *et al.,* 2007; Suthers *et al.,* 2001]. In this field, collaborative argumentation systems are seen as a way through which students can learn to argue about any issue or topics in order to arrive at an agreed-upon position among members of a group [Scheuer *et al.,*2010]. By scaffolding dialogues through argumentation technologies, individuals, not only learn to argue and critical thinking skills [Andriessen, 2006; Bransford *et al.,* 1999], but also they learn about specific domain topics (*arguing to learn*). These two aspect of argumentation are mutually dependent and often no clearly divisible [Koschmann, 2003]. In other words, the acquisition of argumentation and domain skills goes together. This has roused a great notice and, as results, over the last decades, a large and rich array of argumentation technologies as educational systems have been actively developed and tested in numerous researches [Scheuer *et al.,* 2010]. The basic idea is that these platforms improve critical thinking by helping people to support and scaffold their evidence-based reasoning and to facilitate sense making by supporting memory and understanding through knowledge externalization. Numerous studies on argument-based tools have shown their effective in teaching argumentation skills when they are used as educational media [Twardy, 2004; van Gelder, 2006; Toth *et al.*, 2006; Okada *et al.,* 2008].

These results have encouraged the development of CSCW systems based on argumentation as well [Hua and Kimborough, 1991; Karacapilidis and Papadias, 2001; Conklin, 2003; van Gelder, 2003; Karacapilidis *et al.*, 2009]. CSCW has mainly focused on the designing and building of tools able to support different organizational tasks and processes, such as deliberation [van Gelder, 2003; van Gelder, 2006], decision making [Karacapilidis *et al.*, 2009; Karacapilidis and Papadias, 2001], problem solving [Cho and Jonassen, 2002], development of organization memory [Conklin, 2003]. The argumentative aspect of conversations and discussions for accomplishing organizational goals are one of the most important challenges of CSCW, that is how they enable people to cooperate at conflicts [De Moor and Aarkhus, 2006]. Indeed, one of the main advantages of argumentation technologies, respect to the other more traditional CSCW technologies, is that they are able to better manage controversial discussions by letting people to represents properly conflicting point of views.

In the next paragraph, I introduce some of the available argumentation tools in order to better deal with their features and functionalities.

3.3 The argumentation systems

Over time, numerous argumentation systems has been developed that differ each other for several and diverse features, such as applied representation format, used ontologies, type of enabled interaction among users (synchronous or asynchronous). In this studies, in order to present some of the main argumentation tools currently available, I will distinguish them on the basis of their ability to support or not collaboration. Whit this in mind, the range of collaboration alternatives that are today available are:

- **Single-user argumentation systems** support individuals to structure their opinions and thoughts and/or to arrange an argument representation. The well-known example of single-user systems are: *ConvinceMe, Carneades, Araucaria, Athena.* Surely, some of single-user systems can also be used by small groups that share a single computer;

- **Small group argumentation systems** mediate discussion among a relatively small number of learners and offer, usually, synchronous communications. These collaborative argumentation tools allow users to interact each other and with the systems, enabling the development of argumentation skills and discussions about different point of views. Therefore, these tools has to support both argument and communication aspects. Argumentation systems that belong to this category are: *Belvedere, QuestMap, Digalo, Cope_it!, gIBIS;*

- **Community argumentation systems:** are very similar to the small group systems, but are able to support large group of users (maybe more than hundred) and, therefore, are able to represent very large argument maps. Because of the presence of a large number of users, communication is often asynchronous to avoid coordination problems and representation formats are more rigorous. It is a very recent type of argument tool. The unique examples of large-scale argumentation tools are: *Debategraph* and *Deliberatorium.*

Some of the currently argument mapping tools for each identified categories are presented. The choice of these tools among the wide range of argumentation systems available depends on the need to emphasize also their further important features and functionalities, as well as their main differences.

As instances of single-users argumentation systems, I present two of them, that is *ConvinceMe* [Ranney and Schank, 1998] and *SenseMaker* [Bell, 1997]. The choice depends on the fact that these two argument tools let me to introduce two important aspects, namely i) their ability to provide tutorial feedback (*ConvenceMe*) and ii) a different argument representation (*SenseMaker*). Both the systems support the construction of scientific argument and are used exclusively as educational media. In particular, *ConvinceMe* supports scientific reasoning in educational context and lets users to create evidence map, by connecting more scientific-focused primitives such as “hypothesis” and “data” through “explain” and “contradict” links. Additionally, it allows students evaluating arguments by specifying a believability ratings for individual argument elements. This tool provides users with feedback on the acceptability of components in the created graph by running a computational model of reasoning called *ECHO*. This system displays then the evaluation model together with students' believability assessment for the same propositions to help eventually users restructure their arguments and/or revise their ratings [Scheuer *et al.,* 2010].

SenseMaker is a single-user argumentation platform, it has been used also by small group of students in front of the same computer. It distinctiveness feature is that it is one of the few argumentation tools that applies a *containers* representation style of the arguments. Indeed, it allows to visualize argumentations strands belonging together graphically through a frame which serve as containers. Each frame, thus, the claim and the evidence that support or attack it. Another argumentation systems that applies this argument representation is Debatepedia (http://wiki.idebate.org) and *Room 5,* a system for legal argumentation [Loui *et al.,* 1997]. The main advantages of containers format is that it is easy to see which arguments components belong together and are related, while the disadvantages is that it does not allow to have an overview of argumentation as a large maps because of the missing of relations among contributions which are expressed implicitly by the belonging to the same frame (or container).

With regards to small group argumentation systems, I present *Belvedere, Cope_it!* and *QuestMap.* The choice of these different argumentation platforms depends on the possibility to deal with important characteristics of these tools, that is i) a different representation format (*Belvedere*) and ii) the integration of different formalisms to share and represent knowledge with diverse level of formalization (*Cope_it!*). Instead, *QuestMap* has been chosen because it is one of the most known example of CSCW platform. Perhaps, the best and well-known of all educational argumentation systems is *Belvedere* [Suthers *et al.,* 2001]. *Belvedere* was developed to support students in their scientific argumentation, as well as to encourage self-reflection about discussed topic. It is a collaborative argumentation systems and allows students to represent knowledge and discussions as graphs. Surely, this representation format is the most common among the different argumentation platform. Indeed, other graph-based modeling knowledge are *Araucaria* [Reed and Rowe, 2004], *Largo* [Pinkwart *et al.,* 2006], *Digalo* [Schwarz and and Glassner, 2007] *Cope_it!* [Karacapilidis *et al*., 2009], *Compendium* [Buckingham Shum *et al*., 2006; Okada and Buckingham Shum, 2008], *Deliberatorium* [Iandoli *et al.,* 2009], *DebateGraph*. Maybe, its success depends mainly on the fact that it is highly explicit and clear, making argument maps widely intuitive. In *Belvedere,* argument contributions are represented as nodes and links among the nodes indicate the presence of relationships among the different contributions. This graph representation format is an intuitive form of knowledge modelling [Suthers *et al.,* 1995] that allows an easy analysis of argument transcripts and a quick understanding of the state of the debate [van Gelder, 2003; Buckingham Shum *et al.,* 2006]. In the last versions, *Belvedere* has integrated also an additional argument representation format, that is matrix style. It aims at showing implicit or missing relationship among argument elements in which arguments components are the rows and the column, and the cells represents the relations among them. The main advantages of this argument visualization technique is to make immediately visible the lack of link among different aspects of arguments [Suthers, 2003]. However, this style is less intuitive than graph style. In last version of *Belvedere* it is possible to use contemporarily both the representation formats and, hence, hypothetically to benefit from both their strengthens. As *ConvinceMe,* also *Belvedere* provides students with on-demand textual feedback to check for possible weakness in their argument graphs and receive tips on how to proceed. In particular, this system is able to make different types of argument analysis: i. *Domain-specific patterns* (allows to evaluate the validity of argument structure at a syntactic level, i.e. a required contribution type is missing or invalid connections type); ii. *Problem-specific patterns* (the system analyzes differences among between students' and problem specific experts' diagrams). The presence of on-demand feedback has important advantages, that is the feedback will be provided only when request, students will not be flooded with unnecessary messages, are free to decide when their diagrams are ready to have a check and message will seem less authoritative [Suthers, 2001].

Cope_it! is a web-based argumentation systems supporting collaborative learning [Kimble *et al.,* 2000] and discussions. It provides a web-based workspace for representing, storing and retrieving shared and exchanged messages, contents and documents of participants, which may be appropriately processed, transformed and re-used in future discussions [Karacapilidis and Tzagarakis, 2007]. Cope_it!, moreover, is able to support decision making processes as it uses a set of alternative reasoning mechanisms. These mechanisms may take into account parameters such as opinion weights, preferences, number of active position in favour or against an alternative [Karacapilidis and Tzagarakis, 2007] to support the decision making. This platform provides online users with an appropriate means to collaborate towards the solutions of diverse issues. Cope_it! offers three different representation formats that are characterized by three level of formalization: i *Desktop view:* is the lower level of formalization. It allows users to add contents in the most user-friendly way, without forcing them with pre-defined communication rules; ii. *Formal view:* a predefined algorithms of conversion allowed to convert desktop view contents in an IBIS map; iii. *Forum view:* this representation format allows to arrange content in a temporal sequence, showing contents and node type (i.e. statement, argument, document type etc).

Another famous small group argumentation system is *QuestMap.* I introduce it because is one most used CSCW argumentation platform. Indeed, it has been used organizational memory as it allows workers to capture knowledge. The key component of *QuestMap* is the use of a display system, much like an on-line whiteboard, that captures the key issues and ideas during meetings and creates shared understanding in a knowledge team. For instance, the messages, documents, and reference material for a collaborative project can be placed on the whiteboard, and the relationships between them can be graphically displayed. Users end up with a map that shows a history of the conversations that led up to key decisions and plans. QuestMap is being used by major corporations for strategic planning, environmental planning, business process reengineering, and new product design.

The unique examples of large-scale argumentation tools are: *Debategraph* and *Deliberatoium* [Iandoli *et al.*, 2009]. *DebateGraph* is a web-based argumentation tool that allows users to collaboratively create formal representation of debate around complex problems. It support asynchronous argument-based deliberation processes and provides multiple argument representations, such as graph and threaded text. An important feature of this web-based platform is the use of *local view* [Scheuer *et al.,* 2010] to reduce the complexity of large argument maps. This way to visualize argument map is based on the idea to hidden its portions. *DebateGraph* makes use of three argument visualizations, that is *Bubble view, Box view* and threaded view.

Deliberatorium is an IBIS-based argumentation tool developed to support very large groups engaged in deliberation processes around complex problems. It provides a simple web-based user interface that allows user to co-create, edit and navigate an argument map, as well as to communicate each other. The system includes different tools with diverse features and that allow users various actions, such as the *argument map*, *search and history* (allows users to find the posts that have given keywords and to know what other users have done), *people and home* (every users have a personalized home page which lists which articles and comments they have added), *mail, chat and forum* (this tools support different type of communication among users, that is respectively one-to-one communication, public synchronous context and public asynchronous threaded communication), *watchlist* (allows users to specify which articles or post they are interested in so that they can receive automatically notification of eventually its changes), *survey* (allows users to provide feedback about the tool), *help tool* (provides demos and guidelines to support users in doing practice with the tool).

From this very short review of some argumentation systems are emerged certain important elements regard to the these platforms, that is:

- There are different argumentation representation formats, such as graph, matrix, containers and threaded approaches that have their own characteristics, strengthens and weakness. A few argumentation tools apply at the same tame different visual representation of arguments, combining therefore, their potentialities;

- Some educational argument tools automatically analyze users' arguments and provide them with intelligent feedback that and express their believability or acceptability;

- Mainly researchers and practitioners have developed educational systems to support the learning of argumentation skills, but given their ability to encourage critical thinking and evidence-based reasoning, these tools have found large applications also in different fields; indeed there is evidence that argument mapping tools can be effective technologies in supporting collective deliberation [Conklin, 2003; van Gelder, 2003], participatory planning process [De Liddo and Buckingham Shum, 2010], knowledge management [Conklin, 2003; Tergan, 2003], decision making process [Karacapilidis and Tzagarakis, 2007]

- There are too few argumentation tools able to support very large scale argumentation. This is an important gap that could represent a stimulus for future researches.

- Argumentation systems apply different ontologies – explicit specifications of a conceptualization [Gruber, 1993]. Ontologies can be defined as a set of concepts within a domain, and the relationships between those concepts. In Argumentation systems, Ontologies may combine both theoretical perspectives and pragmatic considerations deriving from empirical tests. For instance, both Stegmann *et al.,* [2007] and Suthers [2003] simplified the original Toulmin's model to improve its usability. Surely, the most known and used argumentation ontologies are Toulmin's scheme and IBIS formalism.

In the next paragraph, the strengthens and weakness of argumentation tools will be discussed respect to their ability to encourage collective deliberation and decision making processes.

3.4 Virtues and shortcomings of argumentation technologies

Argumentation theory deals with how human beings should and do reach conclusions through reasoning. Over time, numerous argument-based technologies have been developed to support individuals and groups to use argumentative approaches for improving their reasoning skills. The basic idea is that these platforms support and guide users in their reasoning through the creation of visual objects. Argumentation systems provide users with computer-based interfaces that allow them to create, edit and navigate an argument map. Argument maps can be used to visualize concepts, contents (e.g. annotations), knowledge resources (e.g. websites), as well as links among knowledge elements. Weaving connections among nodes in the maps is the most flexible way to bring ideas and information together in a coherent, concise and compact way. Moreover, by displaying knowledge visually through a spatial metaphor, argument-based platforms are helpful for key cognitive tasks such as sense-making of large amount of (conflicting) information [Uren *et al.*, 2006]. This happens because argument maps make inferential relationships among pieces of information evident, more easier to see and understand [Suthers, 2008]. Moreover, shared, visual representations give new opportunities for focusing collective attention, envisaging new scenarios, coordinating actions and improving comprehension and retention of knowledge [Okada *et al.,* 2008]. The use of graphical representations may be beneficial for many and diverse cognitive tasks, because they force users to express their ideas and opinions to one another in an explicit form, helping to organize and maintain coherence, and serving as "conversational resources" [Andriessen, 2006]. Empirical studies suggested that external visual representations may guide users towards more extensive and complete elaborations of information, consideration of counterarguments and integration of information [Suthers, 2008; Suthers and Hundhausen, 2003; Nussbaum *et al.,* 2007].

In literature, there is evidence that argument-based tools are able to teach and improve argumentation skills (*learning to argue*) [Okada *et al.*, 2008; Pinkwart *et al.,* 2007; Toth *et al.* 2006; Twardy, 2003; Schank, 1995; Stegmann *et al.,* 2007; van Gelder, 2006]. For instance, Suthers [2003] reported some empirical evidence about the ability of these tools in improving student's reasoning abilities; indeed, students that use evidence maps are able to state earlier and more hypotheses and evidence than group that do not use Graph style representation. As users have to conform to specific formalisms based on logical rather than chronological knowledge organization, these argumentation systems encourage evidence-based reasoning and, therefore, promote rational thoughts and improve critical thinking [Buckingham Shum *et al.*, 2006; van Gelder, 2007]. Moreover, researchers have claimed that explicit representations of knowledge through argument maps encourage participants to clarify their thinking [Brna *et al.,* 2001], make this thinking visible to others [Bell, 1997], foster information and knowledge awareness [Englemann and Hesse, 2010] provide resources for conversation [Roschelle, 1996] and can function as a "convergence artifact" that expresses the group's emerging consensus [Hewitt, 2001; Suthers, 2001]. These results have encouraged researchers and practitioners to develop collaborative argument-based CSCW platforms able to support different organizational task, such as i. deliberation process [van Gelder, 2003; Conklin, 2006; Iandoli *et al.*, 2009; Klein, 2009], ii. decision making process [Karacapilidis, 2009; Karacapilidis and Papadias, 2001], iii. problem solving [Cho and Jonassen, 2002], iv. knowledge management ("organizational memory") [Conklin, 2003]. In particular, this work focuses on ability of collaborative argument-based tools to support distributed deliberation and decision making process. Different argument mapping tools able to support deliberation and decision making processes have been developed, such as *Hermes, Cope_it!, QuestMap, Deliberatorium.*

According to several scholars, diverse rational motivations exist to justify the use and implementation of these tools for supporting this organizational process [Conklin, 2003; Klein, 2009; Iandoli *et al.,* 2009; Gurkan *et al.,* 2010; Karacapilidis, 2009]. Firstly, generally speaking, collective discourses and debates can help group members to reason better and argument-based platforms can encourage criticisms and comparison of diverse, alternative and conflicting point of views. Additionally, one of the primary strengthen of argument-based tools is the way captured knowledge is represented and arranged. Indeed, these tools take an argument centric approach which allows groups to systematically capture and represent their debates as argument graphs (or maps) where knowledge is organized logically rather than chronologically. These representation formats have many advantages. Firstly, by supporting critical thinking [Buckingham Shum *et al.*, 2006; van Gelder, 2007], argumentation technologies may lead to more efficient and effective debates and well-grounded decisions [Conklin, 2003; Twardy, 2003; van Gelder, 2007]. This happens because users are required to express the evidence, facts and logic in favour of or against an option [Carr, 2003]. Secondly, researchers claim that argumentation technologies, by supporting logical rather than time-based representation of debates, should reduce some of critical pitfalls of deliberation and decision making processes, such as low signal-to-noise ratio, hidden profile, balkanization, group polarization [Klein, 2009; Iandoli *et al.,* 2009; Gurkan *et al.,* 2010]. In particular, as every contribution appears just once, it radically increases signal-to-noise ratio and, thus, it makes easier to note novel contributions or to "listen" the so-called "small voices" that inspire people to generate creative new ideas.

Another important advantage is that as all related posts appear closer, all content on a given aspect of the discussion is easily identifiable and localizable. This has many implications. Firstly, this makes simpler to find what has and has not been discussed on any topic, fostering a more systematic and complete coverage of it. Secondly, it helps counteract balkanization and group polarization pitfalls by putting all competing ideas and arguments next to each other. On the contrary, users of time-centric tools, usually, tend to self-assemble into groups with individuals share the same opinions and, thus, to see only a subset of issues and arguments potentially relevant to a problems. This leads to people to overemphasize their opinions, as they reinforce each others, and to make more extreme, but not well informed, decisions. Lastly, this representation format reduces redundancy of captured content during the debate. This problem is typical of sharing tools, where content is organized chronologically and widely scattered; this makes very hard to find all contributions that deal with a specific aspects of interest and, thus, might foster unsystematic coverage since users are not aided to identify which area are already well-covered and which need more attention. Furthermore, empirical findings have showed that argumentation technologies are able to favour knowledge elicitation and full information disclosure in collaborative decision making setting [Introne, 2009]. He found that his tool [Reason] is able to significantly reduce a well-know group decision-making pitfall, that is hidden profile effect. The increasing of elicited knowledge by using argument-based tools is confirmed in Jarupathirun and Zahedi's empirical results [2007]. This is another crucial elements for ensuring effective deliberation and decision making processes.

Another important benefits deriving from the use of argument mapping tools is the increasing of discussion coherence. Cho and Jonassen [2002] found evidence that the utilization of argument-based technologies in problem solving setting supports users in the creation of more coherent argument and enables more problem solving actions. This depends mainly on the formalism that users have to use to debate through argument map that encourage users to reason by using evidence and facts. In general, structuring and externalizing are potential aids to increase consistency and coherence of reasoning [Sillince and Saeedi, 1999]. Therefore, argumentation formalism can be considered as a potential remedy for one of problem that are typically encountered in communications supported by traditional current tools (i.e. chats), that is incoherence. According to Suthers [2008] argument maps might increase discussion coherence because the conceptual relevance of users' contributions become more evident and obvious when participants can refers to components of argument map. Moreover, the addition mental demands of argument map creation may lead to more rigorous and well-conceived arguments [Buckingham Shum *et al.,* 1997].

One of the most important strengthen of argumentation technologies, also respect to most common current web-based and not web-based organizational technologies, is that they can be used to build formal, computable and reusable knowledge representations [Conklin, 2003]. Indeed, when used collaboratively these platform support the construction of shared knowledge visualizations which can, additionally, encourage knowledge exchange, sharing and accumulation. For instance, in literature, there are several platforms that are used as organizational memory; this knowledge base can be, therefore, re-used, modified and re-mixed in future discussions [Karacapilidis and Tzagarakis, 2007; Conklin, 2003]. In particular, when these tools are used as problem-solving or decision-making support systems, captured knowledge can represent a starting point or a general reference for next similar problems.

Despite all these advantages, argumentation technology seems to struggle to reach widespread diffusion both in organizations and online communities. Even when used successfully, argument mapping requires users to undergo intensive training to become proficient with the formalism [Twardy, 2004; van Gelder, 2003], strong internal sponsorship, individual commitment and facilitation [Conklin, 2006], and high coordination and moderation costs when the deliberation involves many users [Gurkan *et al.*, 2010].

Many studies have showed that argument-based formalism is hard to use without extended training. Suthers [1999], for instance, in his early work to develop an argument platform, found that strict adherence to an established argument formalism, that is Toulmin's framework [1958] led to usability problem; in other words, Suthers found that too many argument components made students representation worse because of the incorrect use and understanding of the elements. Thus, he should drastically simplify his argumentation system, namely *Belvedere*. Similarly Buckingham Shum [2006] notes that the complexity of IBIS-based systems can be a hurdle to their wide adoption, but suggests that this may be an inevitable elements of argument platforms. Moreover, he claimed that the worth of these platforms justify the initial users' cognitive effort. These findings are confirmed by Conklin [1988; 2006] studies about application of argument mapping tools in workplace settings. His empirical findings emphasized the importance of "cheerleaders" and "facilitators" that sponsored and supported the use of these technologies. Finally, several studies demonstrated that argument-based technologies improve argumentation and critical thinking skills only after extensive training and practice period, usually through facilitators qualified in the argumentation theory. The long and intensive training is required because people do not have, on average, good argumentation skills [Kuhn, 1991] and are subject to several argumentation fallacies [Walton, 1996].

In this work, however, a different thinking to explain the low rate adoption of argumentation platforms is followed. Indeed, a further source of costs can be associated with representation mode used to organize and visualize arguments. As argument-based tools constrain users to follow a specific formalism in developing well-organized arguments when used as medium for debates, graphical representations can be felt unnatural and unintuitive compared to other possible forms of reasoning such as conversation [Clark, 1996]. Moreover, argument mapping tools, by prioritizing the formal representation of contents generated by users over the temporal flow and turn-taking structure typical of conversations, make this technology too constraining in absence of clear and immediate visible benefits perceived by users. Indeed, a substantial amount of research on online argumentation has focused mainly on knowledge representation issues in order to find suitable knowledge formats for representing users' contributions. On the other hand, argument mapping researchers have neglected social and conversational aspects of online interaction. As a consequence the use of argument maps in a collaborative fashion can imply an objectification and formalization of conversation around the knowledge map, as well as the loss of a range of meta-information about participants and the interaction process through which the content is generated. As with any mediation technology, the loss of this meta-information hinders free interaction and makes conversations less efficient [Clark and Brennan, 1991]. The basic idea is that such a loss is even higher in the case of mapping tools because they are strongly object rather than human-oriented. This has raised concerns on the capability of argumentation to act as effective mediator and facilitator of interaction. notwithstanding the remarkably advantages that are expected from its use.

In this work the aim is to investigate how social and conversational argumentation technologies capabilities can be improved, and whether and to what extend these improvements impact on users' performances. With this in mind, the central research question is:

How to retain the advantages of argument mapping and improve their mediation capability?

Therefore, in order to retain the advantages offered by argument mapping tools but at the same time to improve their capabilities to mediate interaction, in the next Chapter, a new technological solution, able to provide real-time visual conversational feedback, will be deeply explained. It is draw on Grounding Cost theory proposed by Clark and Brennan [1991]. Indeed, following Clark and Brennan's theory, the availability of meta-information contained into conversational feedback does not only make the conversation more pleasant from the social point of view, but above all it helps to facilitate the grounding process, that is the construction of shared understanding among participants, thus increasing the efficiency of a conversation.

Chapter 4
Communicating Efficiently to Collaborate Effectively: the Common Ground Theory

4.1 Introduction

Chapter 3 ended with conclusion that low adoption rate of argumentation technologies depends on their poor ability to support free interactions and conversations. Research on argumentation has focused mainly on knowledge representation issues in order to find the suitable knowledge format for visualizing users' contributions disregarding social and communication aspects of interaction, which are very important for fostering interaction and making participation more engaged. Additionally, the utilization of strict knowledge representation formats have led to an objectification and formalization of conversation around a knowledge object (argument map), as well as to the loss of meta-information, embedded into conversation, about participants and interaction process through which the content is generated. According to Clark and Brennan [1991], the loss of this meta-information hinders free communications and makes conversations less efficient.

In this research, a new technological solution, the *Debate Dashboard*, able to improve argument-based systems' mediation abilities will be proposed. In particular, drawing on Common Ground and Grounding Cost theory [Clark and Brennan, 1991], the Debate Dashboard is able to provide real-time visual feedback aiming at compensating the loss of social and conversational information due, mainly, to the mediation of the technology. In the following Chapter, first, Common Ground and Grounding Cost theory will be introduced and then, in line with this communicational theory, a possible solution to tackle the problem will be proposed.

4.2 Common Ground: Clark's Contribution

Language is instrumental for helping people to every day do things [Clark, 1996], such as for planning activities (work, vacations, leisure), discussing, transacting, buying something, teaching and learning, and so on. In order to converse, people have to presuppose to share information and knowledge with their audience. What speakers presuppose guide both what they choose to say and how they intend what they say to be interpreted [Stalnaker, 2002]. Clearly, each participant has own presuppositions about conversation, but it is common knowledge only that part of presuppositions that also all participants presuppose: *one presupposes that* Φ *only if one presupposes that others presuppose it as well* [Stalnaker, 2002]. These presuppositions are what is considered by speakers to be common knowledge of participants in the conversations. This leads to the notion of *common ground* - mutual knowledge, beliefs, assumptions and attitudes among participants [Clark and Carlson, 1982; Clark and Marshall, 1981; Lewis, 1969; Schelling, 1960] built and updated through their joint collaborative activity [Clark and Brennan, 1991]. Common ground at time t_i depends on the common ground at an earlier time t and on the course of the conversation between t and t_i. In line with this, common ground not only to refer to the current status of conversation, but also to the process that led to that condition. Clark and Schaefer [1989] identified two important elements for effective common ground building:

- *Basis:* there is a supposed common ground among participants in a conversation on which they agree.
- *Accumulativeness:* Participants build knowledge on the basis of the presupposed common ground and this depends on making the right addition of knowledge at the right time.

Clark and his collaborators [1991; 1996] claimed that conversation is an example of joint action, being it carried out by two or more individuals which act in coordination each other. In general, a joint action is not a simple execution of actions (i.e. dance, play a duet, converse) among two or more people, but it requires an active involvement by all participants, that is they have to coordinate each other. Clark [1996] distinguished between two types of coordination necessary in every kind of joint activity: *content* and *process*. Coordination of content depends on the shared knowledge about the subject or area of interest (*know that*). Coordination of process depends on shared understanding of rules, procedures and manner in which the interactions will be conducted (*know how*). While content coordination requires a vast amount of shared information, process coordination requires a continual updating of participants' common ground, moment-by-moment. Therefore, according to Clark and his colleagues "*all collective actions are built on common ground and its accumulation".* The effective construction of common ground (or common understanding) is a necessary condition for a successful and efficient communication and collaborative work since it helps people to converse and understand each other.

For instance, when people talk each other they have to do more than just listen and understand; they have to coordinate on the content and on the process [Grice, 1975, 1978]. For instance, when Katja speaks about "her poppies", Sarah must reach the mutual belief that she is referring to her daughters; in addition, Katja have to try to speak only when Sarah is attending to, listening and trying to understand what she is saying and she has to guide her by giving Katja evidence that she is doing just this. During conversation, participants keep track of their common ground and change it moment-by-moment as participants come to share increasingly information.

It is incrementally built on the history of joint actions between communicators [Clark, 1996]. According to Clark and Brennan [1991], during a conversation, participants exchange, in addition to information, evidence and/or requests for evidence, needed to assess whether the listeners have understood or have not understood what the speaker has said. Once such evidence is gained through conversational feedback offered by verbal and nonverbal communication acts, it is used to update participants' shared information. In other words, participants try to ground what has been said during a conversation, that is they make it part of their common ground well enough for their current purpose [Clark and Brennan, 1991; Clark and Schaefer, 1989]. The process of updating of common ground is called *grounding process.* Thus, the building of common ground is viewed as a dynamic and collaborative process. Indeed, from this perspective, Clark and his collaborators proposes an extension of the traditional model of communication by expanding the framework of conversational analysis from the single utterance (or unit) to an interactionally-developed contribution. In the traditional model, the speaker has to produce an understandable utterance and the addressee has to understand it. In the collaborative model, instead, participants has to do more at the same time, that is they have to produce utterances and, then, they have to constantly acquire evidence that these are heard and understood. It is just this process of mutual signalling and checking to be collaborative. According to this view, the process of contributing to a conversation consists both producing content and providing evidence about the understanding of it. So contributing to conversations divides into phases [Clark and Brennan, 1991, p. 130]:

1. *Presentation phase:* A present an utterance *u* for B to consider. He bases so on the assumption that, if B gives him an evidence *e* or stronger, he can believe that she understands what he means by *u;*

2. *Acceptance phase:* B accept utterance *u* by giving evidence *e* that she thinks she understands what A means by *u*. She bases on the assumptions that, once A registers that evidence, he will also think that she understands.

Grounding is mainly evident in the acceptance phase. Indeed, at the end of A's utterance (presentation phase), on the basis of interlocutor's understanding of the utterance, addressee perceives himself in one of four following states for all or part of the utterances. The four states are situated along the spectrum of not hearing the statement to understanding what the speaker meant [Clark and Brennan, 1991, p. 130]:

State 0: B did not notice that A produced an utterance *u*

State 1: B noticed that A produced an utterance

State 2: B correctly heard *u*

State 3: B understood what A meant by *u.*

In other words, when B reaches state 3 with regard to A's utterance, then participants can ground what has been said. Without an acceptance phase, grounding process cannot be begun. Therefore, once a speaker has uttered something, he has to wait for an evidence (positive or negative) about his utterance. Negative evidence indicates that addressee have misunderstood or misheard something and, therefore, speaker has to try to repair the problem. While, three common forms of positive evidence:

- *Acknowledgement:* interlocutor asserts acceptance through some forms of back-channel responses, such as *uh huh, yeah, really* and so on;
- *Relevant* next turn: addressee uttered something of appropriate that induces speaker to think that he or she have understood;
- *Continued attention:* receiver shows to listening or attending to the conversation

Evidence is a crucial elements of grounding process, because it allows people to understand if their audience have understood or have not understood what they have said. It is the pre-condition to get going grounding process.

A central principle of Clark's model is that the grounding process is always adaptive to the current context of communication. In other words, it may be affected by two factors, *purpose* – what people try to accomplish in their communication – and *medium* – the "techniques" available in it for accomplishing that goal and the cost to use them. Additionally, Clark and Brennan claimed that speakers and interlocutors ground what has been said during a conversation by using those techniques available in medium. They will tend to use those methods that lead to the *least collaborative effort.* In general, people tend to conserve their effort or to minimize it in doing what they intend to do. People do not want to work harder than they have to do. According to the *principle of least collaborative cognitive effort*, in a conversation participants try to minimize the work that they have to do to ground what has been said, that is the effort that people do from initiation of each contribution to its mutual acceptance.

A possible way to measure the extent of collaborative cognitive effort is to evaluate the costs of grounding [Clark and Brennan, 1991]. These costs vary on the basis of the medium that people use to communicate. Indeed, when the conversation is mediated by some kind of communication technologies, part of the conversational feedback provided in face to face conversation is either unavailable or can be provided with some extra communication effort. In other words, visual, aural and contextual clues such as facial expressions, body gestures and objects, which may convey additional information, are lacking in any conversation mediated by a technologies. Indeed, further information support and help mutual understanding and grounding process. For instance, in a phone call participants neither can rely on body language to check that the listener understands or that s/he is paying attention to the conversation, or can refer to anything in participants' space to foster the mutual understanding about topic of conversation. Consequently the theory of common ground states that mediated communication is always less efficient than face to face interaction and inefficiency is characterized in terms of grounding costs.

The efficiency of a conversation in terms of grounding costs depends on the presence of a sets of grounding constraints [Clark and Brennan, 1991; Kraut *et al.,* 2002]. These constraints are desirable to reduce the ambiguity and grounding costs in conversation. Indeed, the higher the number of missing constraints, the less able the medium will be for facilitating common ground building and efficient communication. In the following, the ten constraints as defined by Clark and his collaborators are proposed [1991; 2002]:

1. *Audibility: Participants can communicate by speaking*. For instance, telephone, mobile phone and some web-based systems, such as Skype and teleconference tools, have this constraint, allowing, hence, people to hear each other.

2. *Copresence: Users are mutually aware to share same physical environment.* In face-to-face conversation, participants, sharing the same space, can easily and promptly see and hear who is present, what each other is doing and looking at. Sharing the same space allows speakers and interlocutors to use mechanisms

that establish reference to the physical and social world. There are not other media that allow to do it.

3. *Cotemporality: B receives at roughly the same time as A produces*. In most conversations (i.e. face-to-face, on telephone, video-conference etc.) an utterance is received just when it is produced and understood without delay. It does not happens in other media, such as email.

4. *Mobility: Users share the same physical environment and can move around it.* This constraint is important because, for instance, people could use objects to explain quickly something and, thus, foster mutual understanding and grounding. Clearly, this is possible only in the face-to-face conversations.

5. *Reviewability: Utterances do not fade, but can reviewed before being sent.* In some media, such as email, online chats or letters, conversations becomes an artifact and can be reviewed later by participants or, even, third parts.

6. *Revisability: B can revise message for A.* Some media, such as email, short text-based messages or web-based chats, allow an individual to revise and correct it privately before sending it to his interlocutors. On the contrary, in face-to-face and phone conversations, people have to correct their utterance publicly.

7. *Sequentiality: A's and B's turns cannot get out of sequence.* Usually, in face-to-face, phone and video call, turns ordinarily form a sequence that does not include intervening from different conversation with other individuals. With other media, such as email and letters, a message and its reply could be separated by numerous irrelevant or not pertinent messages and activities.

8. *Simultaneity: A and B can send and receive at once and simultaneously.* Sometimes messages can be sent and received by both speakers and interlocutors at once, as when an interlocutors nodding in agreement during speaker's utterance. In general, media do not allow simultaneity, but only

cotemporality, such as online chats that let to convey message just when it is produced.

9. *Tangibility: Participants can touch other people and objects in the physical environment.* This constraint works as mobility constraint in supporting mutual understanding and grounding.

10. *Visibility: Participants are visible each other.* Currently, numerous media allow people to see each other while conversing (i.e. platforms and technologies that support video-call – Skype and videophone)

The more constraints a media can provide, the better the media is for fostering grounding process and, therefore, efficient conversations and collaboration. When one of these constraints is missing, there will be a higher cost of the conversation, because mediation forces people to use alternative grounding techniques. Therefore, the higher the number of missing constraints, the higher grounding costs is. In other words, without these constraints, a major collaborative cognitive effort is necessary for the participants in a conversation to understand each other and ground what has been said. For instance, a video call improves communication over a phone calls because the video-telephony adds visibility or the little pencil icon in a chat gives evidence that the speaker is not away but is writing something in that very moment. On the other hand, text-based compute mediated communication (CMC) is reviewable, allowing participants to re-read message before sending and to easily archive it [Greenspan *et al.,* 2000]. In this way, CMC users have more time to process information.

Each medium and its associate constraints impact differently on collaborative cognitive effort of participants that they have to bear to establish and update their common ground. In turn, this may affect the choice of medium has to mediate and support conversation in workspace.

4.3 Common Ground In CSCW

From the beginning of CSCW field, several heterogeneous theories have been applied to as reference framework for supporting and enabling the evaluation and design of proper collaborative platforms. The wide and various range of theories commonly transferred to CSCW varies from Anthropology field (i.e. Distributed Cognition) to psychology (i.e. Activity Theory and Situated Action theory) and organizational science (i.e. Coordination theory). In this research we focus on human language use [Clark, 1996] and psycholinguistic studies that have provided a theory on social and cognitive factors in communication very useful and important for Human Computer Interaction (HCI), CMC and, obviously, CSCW studies. Indeed, the constructs of common ground and grounding process are often used in this research areas to evaluate the ability of different communication media to facilitate remote interactions and how collaboration can be effected by information and communication technologies. In line with this numerous empirical experiments have been performed to measure and assess the effect of the utilization of different technologies on the construction of mutual understanding. In other words, many studies in CSCW area have been focus on the effect of various media on grounding. In the following, some of these experiments will be introduced, above all, to show the importance and the impact of Clark's theory in CSCW field.

McCarthy *et al.* [1991] compared two forms of text-mediated communication, that is pure online chat and online chat integrated with a "shared report space". They hypothesized that the introduction of shared report space could facilitate the mutual understanding and the grounding process by inserting two important constraints: visibility and co-presence. The aim of pairs of subjects was to solve a design problem communicating only by using the online chat. Some groups used pure online chat, while others used "augmented" online chat (with shared report space). The groups were compared in terms of number of solutions and arguments recorded, and the degree of disagreement was assumed to be inversely related to the development of common ground in each dyad. The results confirmed Clark's theory about the importance of impact of demonstrated that establishing common ground was more difficult for subjects working with the private report [McCarthy *at al.,* 1991].

Another important experiment was reported by Veinott *et al.* [1999]. The aim of this empirical test was to assess grounding process in pairs of native English and non-native English speakers. There are two communicating conditions: only audio and audio supplemented with talking-head video. The basic idea was that the introduction of video (visibility) would improve grounding especially for non-native speakers who presumably start conversations with less common ground. Native speaker perform better than non-native speaker, but the latter showed more improvement of performance when started to use also the video.

Fussell, Kraut and Siegel [2000] studied the effect of communication medium on grounding. In their research, workers were asked to perform manual repairs on a bicycle. They compared three different media conditions: i. side-by-side; ii. Partners separated but able to communicate through a full-duplex audio (visibility); iii. Audio supplemented with video (visibility and audibility). The authors hypothesized that grounding and mutual understanding should be easier in the side-by-side communicative conditions and harder in the audio condition. Results confirmed as hypothesized by them.

Convertino and his collaborators have performed several experiments to assess how common ground develops in a cooperative work setting, in particular, in distributed and synchronous collaboration [2004; 2005; 2006; 2008]. In their studies, researchers [2004] introduced an important novelty in order to better assess the common ground concept applied to collaborative work. Indeed, so far, the principal unit of analysis in Clark's model and subsequent empirical studies was the dyad. According to Convertino, the dyad is, however, a fairly degenerate case of collaborative work group. Specifically, their studies focus on how a geo-collaborative prototype, made up of visualization tools able to support the visibility on team members actions and the (virtual) co-presence [2005], fosters common ground development within working team. This CSCW prototype provides also additional functionalities, such as a shared visual space to exchange further information about cooperative task and process. Several important findings has been derived from their studies about the building of mutual understand in conversation mediated by CSCW system. First of all, empirical results showed that common ground increases over time given that participants increasingly learn about each other, as well as, about the cooperative work processes. These findings support Clark's claim that common ground increases through the joint experience of a task over time [Clark, 1996]. Additionally, they found evidence that teamwork, which use augmented CSCW systems (integrated with multiple visualization tools) perform better than face-to-face teamwork. However, in this case, there is also the impact of the use of a technology with specific functionalities, able to support team's job, on the group's performances. In nutshell, Convertino's studies represent another important reference point for our research for two crucial reason: i. focus on group as unit of analysis (instead of dyad) and ii. Use of visualization tools to support common ground building.

Following this body of literature, in this work, web-based argumentation technologies have been evaluated in terms of grounding constraints in order to better figure out their communication and mediation abilities. In order to do it, an argumentation system has been assessed by using Clark and his collaborators' model [1991; 2002]. Additionally, in line with Convertino's researches, although we have learned much from the studies of common ground in dyadic, in this research, the unit of analysis is the teamwork composed of more than two members performing a specific cooperative task. As we are studying argumentation tools as technology able to support deliberation and decision making process, we aim at analyzing the process of building common ground in cooperative work setting. In distributed, asynchronous deliberation process is quite different from the knowledge exchange process that support conversations [Convertino *et al.,* 2008] as it involves not only effective and efficient communication, but also the coordination of actions and generation of solutions.

4.4 Grounding in Online Argumentation-Mediated Communication for Supporting Distributed Deliberation Process

One of the main advantages of creating a co-located team is that its members incrementally learn about each other and develop mutual understanding effortlessly by working in close coordination, via face-to-face meetings [Convertino *et al.*, 2009]. Notwithstanding, Web 2.0 technologies has provided companies with new tools and models able to enable team members, geographically dispersed, to collaborate [Hayden, 2004] and cooperate without any kind of time and space constraints [Cramton, 2001]. In this work, we focus on web-based technologies able to support more efficient and effective distributed asynchronous deliberation and decision making process. The main Web's effects on deliberation and decision making processes have been: i. increasing information access, ii. fostering more rapid and deeper dissemination of relevant information to all decision makers implied in the process even if geographically dispersed, as well as reducing their associated costs [Shim *et al.*, 2002] and iii. drawing together a wide amount of knowledgeable and interested individual on a scale that has never been imagined. In other words, with the introduction of web-based platforms, collaboration among team members has become increasingly distributed in space and asynchronous in time. Notwithstanding, this greater flexibility in the setting, the ability to easily share large amount of data and put together several individuals comes with a cost that participants have to bear for maintaining and developing common ground. The importance of common ground for supporting efficient communicate, collaborate and work has been showed in numerous studies. [Clark, 1996; Convertino *et al.*, 2005].

As already discussed in the previous chapters, web-based argumentation technologies appear to be the best candidate as technology able to support more effective and efficient distributed asynchronous deliberation and decision making process. Notwithstanding several advantages deriving for the utilization of these technologies, they seem to be not able to efficiently support free mediation and interaction. As researchers have mainly focused on knowledge representation issues in order to find suitable knowledge formats for representing users' contributions, they have neglected social and conversational aspects of online interaction. Therefore, the use of argument maps in a collaborative fashion implies an objectification and formalization of conversation around the knowledge map, as well as the loss of a range of meta-information about participants and the interaction process through which the content is generated. As with any mediation technology, also in the case of argument mapping tools, the loss of this meta-information hinders free interaction and makes conversations less efficient [Clark and Brennan, 1991]. Such a loss is even higher in the case of mapping tools because they are strongly object rather than human-oriented. Generally, the availability of meta-information contained into conversational feedback does not only make the conversation more pleasant from the social point of view, but above all it helps to facilitate the grounding process, i.e. the construction of shared understanding between participants, thus increasing the efficiency and effectiveness of a conversation [Clark and Brennan, 1991; Convertino *et al.*, 2008].

In order to better understand the amount of the loss information we used Clark's and his collaborators' model [1991; 2002] to evaluate the efficiency and effectiveness of them to support communication [Fussel *et al.*, 2000; Kraut *et al.,* 2002; Convertino *et al.,* 2008]. In other words, we aim at assessing their communication and mediation abilities. In particular, an argumentation technology has been evaluated in terms of grounding constraints that it is able to provide users. Indeed, according to Clark and his collaborators, the more constraints a media may provide, the better the media is for fostering common ground building and, thus, efficient conversation. As this research focuses on online distributed, asynchronous conversation mediated by argument-based technologies, the descriptions of constraints proposed by Clark and his collaborators [1991; 2002] has been modified and adapted to our application context. In Table 1, the list of constraints with original and our adapted definitions is showed.

Thus, according to Clark's theory, when people communicate and collaborate by using argument mapping tools, they have to bear very high grounding costs. This depends on the lack of numerous constraints; in fact, eight out of ten constraints are missing, namely *Copresence, Audibility, Visibility, Tangibility, Mobility, Cotemporality, Simultaneity* and *Sequentiality.* Instead, in online argument mapping tools, users' contributions can be both reviewed by all users (reviewability) and revised privately before being sent (revisability). In other words, argument mapping tools do not allow users to see each other, share the same environment, know who is (virtually) participating to the discussion, what users have done in their past participations, the reply structure of conversation and so on.

Table 1. Affordance in communication media

Affordance	Clark *et al.*'s definition	Our adapted definition
Audibility	Participants hear other users and sound in the physical environment	Idem
Copresence	Users share the same physical environment	Participants are mutually aware that they share a virtual environment
Cotemporality	B receives at roughly the same time as A produces	Idem
Mobility	Users can move around physical space	People can move around in a shared virtual environment
Reviewability	B can review A's message	Message are stored in online repositories for later revisions
Revisability	B can revise message for A	Message stored in the repository can be revised before being sent
Simultaneity	A and B can send and receive at once and simultaneously.	Idem
Sequentiality	A's and B's turns cannot get out of sequence.	Participants can reconstruct the reply structure
Tangibility	Participants can touch other people and objects in the physical environment	Participants can touch other people and objects in the virtual environment
Visibility	A and B are visible to each other	Participants see the actions of other users in the shared virtual environment

Our adaptation from Clark and Brennan [1991] and Kraut *et al.* [2002]

Compared to face-to-face conversations, provide less feedback and fewer contextual cues; indeed, in argument-based conversations the provision of conversational feedback and contextual cues is usually more expensive as people are forced to use alternative techniques rather than the cheapest facial expressions, postures, body signals and reference too objects. Put differently, usually conversation is a multi-modal process, that is it involves more than verbal communication, such as facial expressions, body gestures and postures that help workers to communicate, understanding each other and grounding what has been said. In general, any conversation mediated by a technology is considered less efficient and "less-rich" than face-to-face conversation, because it reduces the possibility to use non-verbal and less costly communication forms. For instance, in face-to-face conversation, interlocutors could nod in agreement or for showing attention, while in other mediated conversation, such as phone-call or computer mediated conversation, they have to say or type the word something. Clearly, the cost of this acknowledgement is higher in mediated than face-to-face conversation, as wording and typing is surely harder and more costly than nodding in agreement. The techniques that people may use for communicating and grounding depends on the medium and the constraints that it imposes on conversation.

The main reason explaining the poor performance of argument mapping tools in terms of grounding costs is that they are objected-oriented technologies: the primary objective of an argument mapping tool is to generate a knowledge object in the form of map able to capture and organize knowledge provided by many contributors during a debate. Differently from other collaboration technologies, they are not explicitly designed to support interaction and keeping track of the communicative acts developing during the process. Therefore, the lack of several constraints, object-orientation, formalization and disruption of the conversation reply structure due to spatial reorganization of information entails high grounding costs and consequently difficulties in developing common ground and support efficient/effective communication. In addition, being argument-based conversations asynchronous, participants loose also all real-time feedback and back-channel cues that are so useful for minimizing misunderstanding and showing attentiveness. This implicates a further collaborative effort to the participants as they should use alternative techniques to reach the same results (i.e. type something or ask a clarification). The difficulties of building common ground may prevent users to exploit the benefits usually associated to the use of argumentation technologies; such benefits actually assume the availability of well-formed maps or at least that users are in the conditions to create such maps. If grounding costs are high, the chances for users to create good maps will be low, unless substantial effort is provided by external moderators charged with the task of mapping in real time the contributions provided by many users. Unfortunately moderation can become very costly when the tool is intensively used by a large enough group of users.

In order to deal with this problem and to improve the cost/benefit ratio of using argumentation technology our proposal is to develop an augmented argument mapping tool able to retain the traditional advantages offered by argumentation technologies and to deliver at the same time a richer set of meta-information aimed at fostering social interaction among users and supporting the construction of mutual understanding. We call such an "augmented" Debate Dashboard because themed-information is delivered mostly through visual widgets, built upon and connected to the argumentation tool, that are expected to support participant conversations. The basic idea of the Debate Dashboard is to make visible information that in face-to-face conversation is immediately available and that in computer-mediated communication is hidden or missing.

In the following paragraph, a model able to support and improve argument-based technologies' mediation and communication abilities will be introduced and explained.

4.5 A Theoretical Model for Augmenting Argument Mapping Tools

Online argument mapping tools leave users blind to a range of information that is commonly readily available in face-to-face interaction [Smith and Fiore, 2001], hampering free communication. Indeed, as claimed by Clark and Brennan [1991], when a conversation is mediated by a connection technology, most of that information promptly and effortlessly accessible in face-to-face conversation are missing. As emerged in the previous paragraphs, this information is very crucial for successful, effective and efficient discussions since it fosters and helps users understand each other and ground what has been said with least collaborative cognitive effort. Therefore, according to Grounding theory, in order to enable freer, easier and smoother interaction and communication, we should make available and visible all that meta-information.

In addition, since the general aim of this research is to improve argumentation technologies' mediation and communication capabilities and, contemporarily, retain the advantages deriving from their utilization, we should consider other two critical inherent aspects (or limits) of online conversation mediated by these technologies.

They are:

- The need to build of users' sense of membership in virtual community. This aspect concerns mainly inherent characteristics of collaboration and participation in online communities. Indeed, in literature there is evidence that several online communities fail because of the lack of involvement and participation by their members [Kim, 2000].

- The persistence of online conversation leads to information overload. Indeed, when the number of participants increases, the number of contribution can be substantial, leading to cluttered and hard-to-read argument maps [Scheuer *et al.*, 2010].

Therefore, in line with as emerged from carefully analysis of distributed, asynchronous conversations mediated by argumentation technologies and from literature review, in order to augment argumentation tools' mediation abilities, retain the advantages deriving from their utilization and support their widespread adoption, we should provide users with three different type of meta-information about:

- Online users

- Interaction process through which the content is generated

- Generated content during conversations

On the basis of these identified crucial elements for effective and efficient conversations, three different categories of feedback has been defined. These different classes of feedback aim at compensating the lost of crucial meta-information that may make conversation, mutual understanding and grounding process easier, cognitively "cheaper" and smoother (Figure 6):

- **Community feedback (who):** this set of feedback allows users to know who are the community members, to visualize the community structure and, in particular, to foster the development of a sense of membership.

- **Interaction feedback (how):** this class of feedback let users to understand how the members of online community interact and what is happening in the online community, supporting mutual understanding and grounding process

- **Absorption feedback (what):** this feedback is about the content generated through interaction among users and its organization. This feedback should help users make sense of large amount of produced content.

In nutshell, the basic idea is that, by providing this feedback, people can be aided to communicate in better and easier ways, to reduce misunderstanding and to reduce cognitive costs associated with the use of a connection technology to communicate and collaborate.

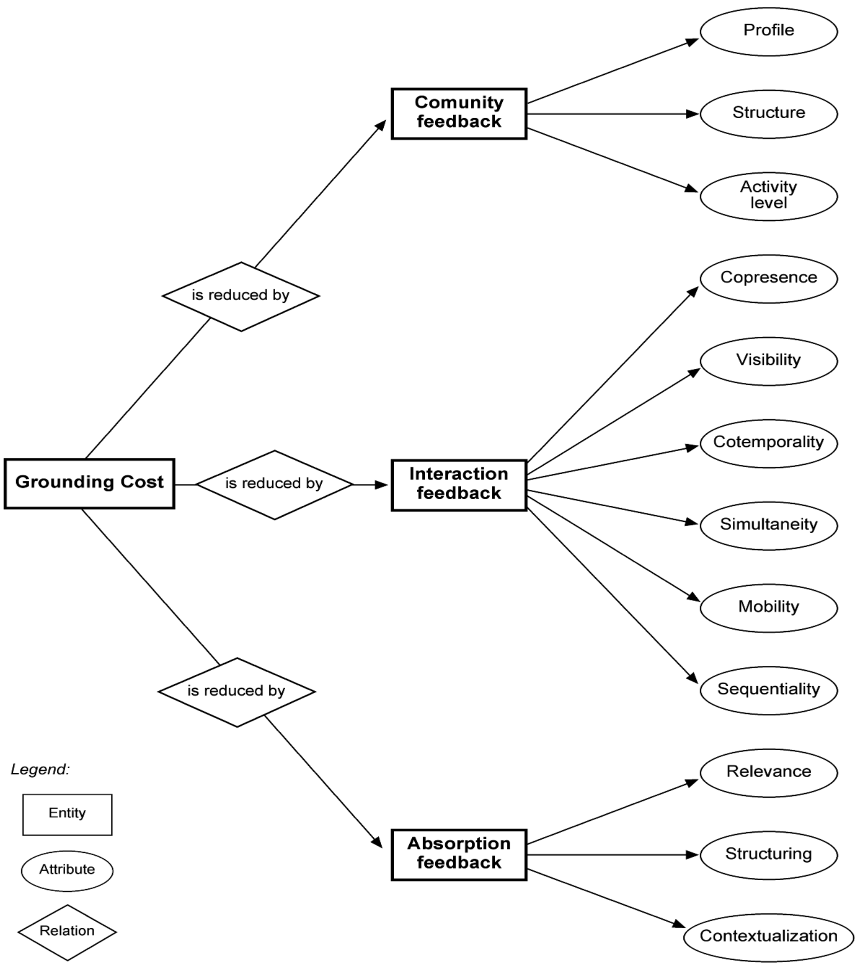


Figure 6. Supporting common ground building framework

In the following paragraphs, each indentified class of feedback that we want to provide through new technological device in order to support common ground building. Moreover, for each class of feedback, we then identify the attributes that need to be considered in order to compensate the lack of information.

4.5.1 Community Feedback

By providing this class of feedback, we aim at supporting the development of a sense of community in a virtual setting and to improve the acquaintance of other community members and knowledge about past actions of community. Indeed, in literature there is evidence that the cause of failure of online community is just the lack of the sense of membership and belongingness to a group.

In literature, there is no universally accepted definition of the term "sense of community", although there are several useful and interesting conceptualizations. Among these, we show descriptions that better adapt also to the virtual context, that is those that focus on what members feel and do together, rather than where and through means they do things. For instance, Unger and Wandesman [1985] defined sense of community as feeling of membership and belongingness to community or a social group. Another interesting definition is that proposed by Sarason [1974] that describes the sense of community as the perception of similarity to others and the recognition of existence of interdependence with others. According to both definitions, the most crucial features of community are mutual interdependence among members, sense of belonging, connectedness and shared values and goals. In their studies, Blanchard and Markus [2002] found that the development and the maintenance of the sense of community depends mainly on the creation of identity and the identification of other members. By creating identity for themselves (i.e. through providing personal information or through frequency and content of contributions) and allowing the identifications of others, online community members bring a community out of anonymous and invisibility. Therefore, the nameless and faceless, in same way, are recognized and become people to whom one feel an attachment and mutual obligation

[Blanchard and Markus, 2002]. This is a very crucial factor that differentiates virtual communities from the physical ones; indeed, this distinction may depends on the fact that participants in virtual communities can appear and feel much more anonymous than members of physical communities.

Several researches provide evidence that strong feelings of membership may not only increase participation in the community, but may also increase the flow of information and knowledge among all members, cooperation among members, commitment to group goals, members' engagement in community activities and satisfaction with group effort [Bruffee, 1993; Dede, 1996; Royal and Rossi, 1996; Wellman, 1999]. Therefore, in line with this, the development of a sense of membership should principally implicate the increasing of users' participation and engagement, as well as improvement of groups' performances. In order to do it, three different sub-classes of feedback have been provided:

- **Profile:** community members' personal information, such as name, age, place of birth, job/occupation, hobbies etc. The basic idea is to support a better mutual acquaintance among members and support the creation of identities for themselves and the identifications of others. According to Cutler [1996] *"the more one disclose personal information, the more the others will reciprocate, and the more individuals know about each other"* (p. 326).

- **Social structure:** shows social network structure of online community. The phrase "social network" refers to the set of actors and the ties among them. In other words, social networks are abstract visualization structures that help individuals understand the relationship among interconnected individuals. Social Network Visualization could be defined as one of approach to studying collaborative environment, as well as collaborative network. This feedback is very important because allows members to gather much information about online community and its dynamics. First, members can better know who speaks to whom and the frequency of relationships. Additionally, they can gather further information about users' role in the online community. Another important elements is that, by knowing user's personal social network, it is possible to understand and know further aspects about the single users. This feedback should let to increase both the sense of membership (by visualizing own social network, individuals feel part of it) and mutual knowledge.

- **Community's history (about created content):** holistic view about community past activity. In this case, users can have concise and compact information about the most recent, popular and connected users' contributions. This feedback provides information about activity and participation level of community as whole.

In general, this feedback aims at supporting online users to make sense of state of the online community and discussion. The basic idea is to motivate users' participation by visualizing the community and the level of participation of all community members, expecting that such social visibility may stimulate users to engage in conversations. By participation we mean those activities which the community benefits and that indicate involvement in it, such as contributing to the conversation through the creation of posts and links. Therefore, in line with this, the provision of this feedback should create awareness about the other users and aid them to gather information that, in turn, should help them to pitch into conversation easily and feel promptly part of a community. Additionally, the gathering further information about other community members support the development of mutual knowledge about each other that may help people understand better and, thus, ground what has been said.

4.5.2 Interaction feedback

As specified in the previous paragraphs, Clark and Brennan [1991] and Kraut *et al.* [2002] identified ten constraints that a medium can impose on the communication between people to foster mutual understanding and grounding process. When one of these constraints is missing, there is a higher cost of the conversation, because mediation forces people to use alternative grounding techniques. In line with this, the provision of interaction feedback aims at compensating the lack of these constraints that are crucial in supporting the construction and development of common ground.

Following Clark and Brennan's theory, argumentation technology has been evaluated in terms of set of grounding constraints that they are able to provide and, thus, in terms of grounding costs that users have to bear to communicate in an efficient way. Indeed, as already discussed in the previous paragraph, in the case of online argument mapping tools, eight out of ten constraints are missing. While these platforms let users to both review (*reviewability* constraint) and revise (*revisability* constraint), they do not have the following constraints: co-presence, audibility, visibility, tangibility, mobility, co-temporality, simultaneity and sequentiality.

Moreover, it is necessary to make a precision about what feedback we can and want to provide. Indeed, of course, we do not consider feedback aimed at compensating the loss of *Tangibility* and *Audibility* give the difficulty or impossibility to deliver them in a virtual setting. With regard to the *Simultaneity,* another important clarification has to be introduced. According to Clark and Brennan [1991], the presence of this constraint lets participants to a conversation to send and receive at once and simultaneously different messages. For instances, in face-to-face conversation, it happens when an individual smiles during speaker's utterance. In this case, in the same moment, there is both presentation phase and acceptance phase, given that the smile may be interpreted as an signal of attentiveness and understanding. Simultaneous utterances are possible also by using some teleconference systems that show what both parties write letter by letter in two distinct space of the screen. As research's focus is online asynchronous conversations, this constraint is not adequate and not possible to the application context and, for this reason, we decide to not consider it.

Therefore, by providing this class of feedback, we aim at supporting easier and smoother conversation, the construction of common ground and mutual understanding among users. With in mind this and in line with Clark's model and inherent features of argument-based technologies, the provided feedback, belonging to this class, is:

- **Copresence:** through this feedback, users can know who is online, therefore, they are mutually aware whit whom they share a virtual environment. The knowing who is online contemporaneously, should enable conversation more easily. In other words, this feedback may push people to engage a conversation with users that are online, because when people virtually "meet" they are reminded about their existence, know their availability for communication and have the feeling to be "listened". Repeated "virtual" encounters support the development of common ground.

- **Cotemporality:** as we are focusing on asynchronous conversations, participants to the discussion cannot be received message at roughly the same time as it is produced. When there is this constraint people can readily receive and understood the message without delay; instead, it is not possible in asynchronous media. The delay makes harder the construction of common ground. By introducing this feedback, people can immediately know whether and when a post has been created, reducing the time interval among post's production and its reception, as well as understood or misunderstood. Indeed, if someone does not understand the content of the message can ask a clarification and speakers at once repair the faults. Indeed, as faults tend to snowball, speaker should want to repair them as quickly as possible [Clark and Brennan, 1991].

- **Mobility:** provided information concerns where online users "move" in the virtual environment. Clearly, we should simulating users' movement among different topics or discussion groups. This may support the building of common ground because users can gather further information about other members, such as which discussions they participate in, what are the last "movement", what are they favourite topics. This set of information shapes the basis of online users' common ground and that will be updated through joint experience over time.

- **Sequentiality:** in the case of online argument mapping tools, users' contributions are provided in a logical rather than time-based representation. Thus, the lack of the sequentiality constraints is a choice. In the same time, this property, which is supposed to be an important element of online argument mapping tool, it is actually one of the major responsible of disruption of smooth interaction. This happens because speakers do not have immediate evidence about hearers' understanding of their utterances and so they cannot repair eventual misunderstanding. This involves a further cognitive effort to ground exchanged knowledge during a conversation. The basic idea is to provide users with a temporal representation of conversation so that they can visualize the reply structure. We aim at introduce a system able to reproduce reply structure.

- **Visibility:** through this feedback, we want to provide users with information about other members' actions relative to the specific discussion or collaborative task. The information that we would like to provide are some stats about users' activity, such as number of posts and connection created about a specific topic. In this way, users' actions are visible to the other community members. This should provide users with additional information on the other team members and, thus, increase common ground.

4.5.3 Absorption feedback

In literature, there is evidence that when the number of participants increases, as consequence, the number of "boxes and arrows" intensifies and argument maps become cluttered and hard-to-read [Scheuer *et al.*, 2010]. Indeed, when argument maps are too large, it is very difficult to have an overview and grasp all information. This leads to the so-called "spaghetti" images [Hair, 1991; Loui *et al.,* 1997]. Additionally, because of permanency of the online conversation on argumentation technologies, over the time information and knowledge tend to accumulate, leading to information overload that, in turn, makes harder users' sense-making of this wide amount of knowledge. As already mentioned, for effective and efficient communication, people need to associate the same meaning for the same piece of information. When it occurs at the community level, a common sense has been built for the entire community. However, reaching common sense at community level require a process of sense making. Sense making is a motivated and continuous effort necessary to understand connections among different people, concepts and events, in order to anticipate their trajectories and act effectively [Klein *et al.,.* 2006]. The way people make sense of situations depends on their pre-existing frame (or scripts) which are internal images of external reality [Rudoloph, 2003]. The purpose of a frame is to define the elements of the situation, describe their relations, filter out irrelevant messages and highlight relevant messages. Indeed, the frame recognizes the information as they become available and, in the same time, it is changed by those information. Indeed, when people realize that data do not fit into the frame that they are using, a surprise is generated and sense making starts to modify the frame or replace it with a better one. In other words, through the sense-making, people structure the unknown [Waterman, 1990].

The problem is that when argument maps become too large and therefore, hard-to-read, not clear and understandable to participants, they are not so able to support the sense making process [Selvin and Buckingham Shum, 2009]. Clearly, the lack of support for users' sense-making process implicates a higher complexity in the construction of mutual understanding and grounding process. Indeed, sense-making can be considered a preliminary phase of mutual understanding and of grounding process. Indeed, as collective actions start new information leads to a continuous update of individual frameworks (or frames) which in turn shifts the understanding at a community level from one state to another. Therefore, supporting individual sense-making means supporting collective common ground building.

In order to tackle this problem, we defined this class of feedback. Indeed, the provision of it aims at supporting sense-making of conversation and helping users to mutually coordinate on the content [Clark, 1996]. In addition, absorption feedback should allow users to understand the structure of the discussion and its evolution, as well as to support its exploration and analysis. In other words, through this feedback, the usability of the knowledge-object, that is the map, should improves, allowing users to pitch in the conversation in the right place.

The sub-classes of feedback we have identified for this category are:

- **Relevance:** we will provide feedback that helps users individualize and recognize chunk of relevant information (e.g. topic clusters). This feedback is very useful when the map develops and information accumulates, because the users have many difficulties to "move" through it and this require a major cognitive effort to them; thanks to this feedback the usability of the map improves, allowing users to find topics of their interest. In nutshell, this feedback helps explore a large amount of information into more manageable pieces [Yi *et al.,* 2008] and pitch in the conversation in the right place.

- **Structuring:** this feedback may help users create relations and links between different chunk of information. In this way, people can find trends, patterns or structures in a huge amount of data. Through this procedure, people may not only find what they look for but also discover new knowledge that they did not expect to find.

- **Contextualization:** this feedback is expected to help individuals reduce the gap between new information and user's mental model, thereby reducing the cognitive load to "reframe" the new information. It is supposed to aid users to contextualize new information. In other words, it supports people to extract contextualized information from the conversational context and to help them decide on what information is relevant and what explanations are acceptable [Salancick and Pfeffer, 1978]. Extracted information provides points of reference for linking ideas to own personal frame.

We expected that increasing of mutual understanding and improvements of grounding process depended on three crucial online conversation dimensions, that is feedback about virtual community, interaction process through which the content is generated and generated content.

First, by creating a sense of community, users feel to belong it and share with it values and purposes. In this way, collaboration is more satisfying and gratifying and users tend increasingly to participate. In line with Clark's claim [1996], this leads to increasing of common ground as participants even more learn about each other, as well as, about the cooperative work processes. Second, through interaction process, we aim at reducing collaborative cognitive effort that users have to bear to understand each other and ground what has been said. The basic idea is to allow users gathering information that are lost because of the lack of crucial media constraints. According to Clark and Brennan, the presence of these constraints helps users communicate and understand each other, reducing collaborative effort because they let them to use costly conversational and grounding techniques. Third, by providing absorption feedback, we aim at supporting sense-making of large amount of information and knowledge. Indeed, when maps are too large, it is more complicated grasp and make sense of all the generated content. Individual sense-making of the conversation is the first step for being able to foster successful common ground building at community level.

In conclusion, by providing these categories of feedback, we aim at supporting efficient and effective common ground construction among online users involved in distributed asynchronous deliberation process.

The following paragraphs deal thoroughly with how these categories of feedback have been provided users. As already mentioned, our proposal is to set up a new technological device, the Debate Dashboard, able to retain the traditional advantages offered by argumentation technologies and to deliver at the same time a richer set of meta-information aimed at fostering social interaction among users and supporting the construction of mutual understanding.

4.6 The design of the Debate Dashboard

Numerous researchers have been focused on the analysis of the impact of the provision of conversational feedback and hidden information, by using visualization tools, on quality of discussion, its outcome and interaction processes among users. Shneiderman [2000] argued how disclosing patterns of past performances, providing rich feedback about users and generated content are best practices for supporting online conversations. Erickson *et al.* [2002] discussed the importance of making socially-relevant hidden information visible in interactive communities in order to support smooth, reflective and productive conversations through synchronous and asynchronous tools. In addition, other previous studies have shown that information visualization tools may facilitate information sharing, problem solving process and collaboration both in collocated group [Edelson *et al.,* 1996; Ryall *et al.,* 2004] and in remote setting [Mark *et al.,* 2003; Aruna *et al.,* 2008]. Information visualization tools are able to reduce task completion time and increase productivity on many information retrieval task and data analysis as well [Hendrix *et al.,* 2000; Stasko *et al.,* 2000; Veerasamy *et al.,* 1996] Other researchers have built information visualization systems attempting to provide large amount of information about the presence and activity of their users in a consolidated and easy-to-read way [Donath *et al.*, 1999; Viegas and Donath, 1999; Dave *et al.*, 2004; Suh *et al.*, 2008].

According to Card *et al.* [1999], the main aim of Information Visualization is to provide insights and help users identify trends, patterns, unusual occurrences and make comparisons in datasets. Information visualization tools could represent a way to directly perceive data and discover knowledge and insights [Nguyen and Zhang, 2006], to see information that is hidden or unavailable in a textual representation, making it apparent, to help the reader understand and apprehend the discussion's structure and history, to become familiar with its community, to permit easy and intuitive interaction with the large amount of information [Dave *et al.,* 2004], and to explore and to understand the information [Streit *et al.,* 2008].

In the last years, in Human Computer Interaction (HCI) and Computer-mediated Communication (CMC) literature, many researchers and practitioners propose the use of visualization tools to provide different type of information and feedback about virtual community, users' activity and participation by using different metaphors. For instance, the Babble System [Erickson and Kellogg, 2004] visualizes a conversational area (a chat room) as a cookie and online users as marbles. The marbles of active people are represented near the centre of the cookie, while ones of inactive people are represented near the periphery. Marbles outside of the cookie symbolize people involved in different conversation. In Chat Circles [Viegas and Donath, 1999] people are represented by coloured circles. They brighten when an user edits a post and they grow to accommodate the text inside them. They fade and diminish in periods of silence, though they do not disappear completely so long as the participant is connected. In subsequent version of Chat Circles (Chat Circles II) [Donath and Viegas, 2002], the circles move around the screen simulating users' movements among different topics in the chat, leaving a trace that fades over time. In Coterie [Donath, 2002] users are represented as coloured ovals that bounce and became brighter when an user speaks through the online chat. Different metaphors to represent users' past interaction and activity in forum and newsgroups has been used in PeopleGarden [Xiong and Donath, 1999], BulB [Mohamed *et al.,* 2000], Communication-Garden System [Zhu and Hsinchun, 2008]. For example, PeopleGarden uses flowers and garden metaphor. Users are represented by a flower and the longer they have been involved, the higher the stem. The petals represent the posts and initial postings are in red, while replies in blue. Each thread (or discussion group) is a garden full of flowers. In BulB the stems represent the thread and their height represents how long they are active. The stem-head can represent either the development of thread (each line is a post) or user thread participation (each colour is an user). Communication-Garden System has two different visualizations. Thread visualizer employs a floral representation to graphically depict the liveliness of a thread. The flower representation allows to represent the number of messages (petals), number of participants (leaves) and time duration (height of stems). People visualizer employs the same flower, but the provided statistics regard to the single users. In this representation the flowers (users) have the faces to differentiate from thread visualizer.

By using intuitive metaphors and proxies that do not require complex interpretation, researchers are able to provide large amount of information about users, their participation, activities and relationships that should improve systems' usability and reduce cognitive effort for understanding, perceiving and exploring patterns and trends in dataset. Information visualization offers the unique means that enable users to handle abstract information and facilitate cognition by taking advantage of their visual perception capabilities [Nguyen and Zhang, 2006; Card *et al.,* 1999] and to compensate humans' limits. Through visual representations, it is possible for human beings to use more of their perceptual abilities in understanding and processing information. This ability of the human mind to rapidly perceive visual information makes information visualization a powerful and necessary tool for information discovery. Thus, it is possible to claim that the intention of information visualization tools is to optimize the use of our perceptual and visual-thinking ability in dealing with phenomena that might not readily lend themselves to visual-spatial representations [Chaomei Chen, 2002].

In line with as emerged from the literature on visualization tools, we decide to exploit visualization tools' capabilities and strengthens to effectively and efficiently provide identified conversational and social feedback. In particular, we chose to define and implement a set of visualization tools built upon and connected to the argumentation tool, that work in a closely coupled way. This means that multiple representations are linked together in a way that any manipulation and change of values in argument map view creates a similar change in the linked ones. Moreover, as users are able to use this visual representations also to explore the data, we think that this will allow users to look at data through different perspectives, perceive new information and discover new insights.

Therefore, we selected and created a set of visualization tools that constitute the Debate Dashboard. In accordance with Few [2004], the Debate Dashboards can be defined as a visual display of the most important information needed to achieve one or more objectives, consolidated and arranged on a single screen so the information can be monitored at a glance. It allows to visualize large amount of information and to provide feedback in a consolidated and easy-to-read way. The choice of visual widgets depends on the need to avoid to require users further cognitive effort to understand and interpret data and information since, as already discussed, the use of argument mapping tools is not so simple and without cognitive load. The developed Debate Dashboard is able to provide users with three categories of visual conversational and social feedback, as defined in the previous paragraphs, about: i. users, ii. the interaction process through which content is generated, and iii. the generated content. In other words, the main aim is to set up a Debate Dashboard in order to aid users to monitor and make sense of discussions, showing them feedback about participants, their activities with respect to the conversations and the evolution of the generated content. The dashboard not only makes the data available in appropriate and concentrated fashion, but also represents these data in easy-to-follow way. Therefore, the dashboard can be seen as a mediating system between the mapping technologies and the need for information [Beuschel, 2008].

We distilled the Debate Dashboard features by building on results of a literature review on Web 2.0 tools for data visualization. In particular, we have thoroughly reviewed thirty visualization tools (more details in Appendix A) and a survey of the most famous social networks, chats, blogs such as Twitter, Skype, Facebook etc [Quinto *et al.,* 2010]. We assessed each visualization tools in terms of the feedback framework reported. In the review, we focused principally on those visualization tools already implemented and in use in real online communities. Some of these visualization tools are available online and user can directly upload their data and then produce graphic representations for others to view and comment upon (i.e. see http://www.visualcomplexity.com/vc/; http://www-958.ibm.com/software/data/cognos/manyeyes/; http://prefuse.org/).
Through the review of all these tools we have to carry out a requirements analysis in order to understand what their key features are, how they work, what kind of feedback they provide, what kind of feedback is considered the most important in literature, what are the "best practices" used; in other words, they represent our benchmark and we used them to "inspire" the design and in the implementation of the visual widgets that compose the Debate Dashboard.

In conclusion, the Debate Dashboard is supposed to support users in communicating better and more easily, reducing misunderstandings, facilitating the grounding process and diminishing its costs. Moreover, we expect that the improvement in the grounding process may also improve some users' performances such as efficiency and outcomes.

As already mentioned, the Debate Dashboard has been built upon a web-based argument mapping tool, namely Cohere (an experimental version is available at http://socialmap.open.ac.uk/). In the following paragraphs, we deal with, first, Cohere and then we present each visualization tool that composes our dashboard.

4.6.1 A web-based Argument mapping Tool: Cohere

Cohere is a web-based asynchronous argument mapping tool whose purpose is to support on-line collective argumentative debates. It is a Knowledge Media Institute technology, developed by a team group composed by Simon Buckingham Shum (Technology Champion), Michelle Bachler (Developer) and Anna De Liddo (Research Associate).

Viewed through the lens of contemporary web tools, Cohere sits at the intersection of web annotation (e.g. Diigo; Sidewiki), social bookmarking (e.g. Delicious), and mindmapping (e.g. MindMeister;), using data feeds and an API to expose content to other services [De Liddo and Buckingham Shum, 2010]. Cohere adopts the IBIS approach (Issue Based Information System) [Kunz and Rittel, 1970], which allows to create an argument maps (Figure 7) made up of three key elements: i. *issue* to be answered, ii. *positions* (or ideas) as alternative possible solutions to issues, iii. supportive or challenging *arguments* about proposed ideas.

With Cohere users can create posts to express their thoughts and pick up an associated icon representing the rhetorical role of that post in the wider discussions. Moreover, users can explicitly connect their posts to any other which is relevant to what they want to say. They can do so by making a connection between posts, which explain the rhetorical move they want to make in the conversation. Finally, they can create discussion group to converse and debate about any kind of topic or theme.

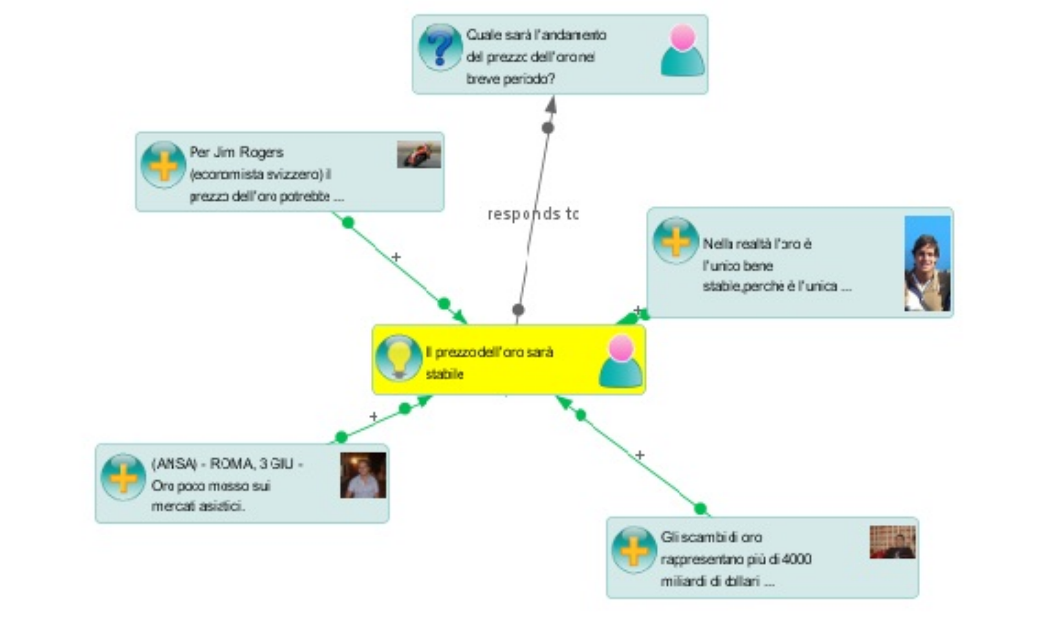


Figure 7. Cohere's environment in which online dialogue is represented as semantic network of posts

Cohere allows representing debates in more compact way compared to traditional textual representation by creating semantic networks. By structuring and representing online discourse as semantic network of posts Cohere enables a whole new way to browse, make sense of, and analyze the online discourse. Indeed, through providing a logical rather than chronological organization of discussions, Cohere supports the representation of the conceptual structure of a debate. In addition, Cohere allows reflecting on conceptual structure of debates and therefore to support the users in the answering to crucial questions such as: What are the key issues raised in the conversation? How much support is there for this idea? Who disagrees, and what evidence do they use? Usually, this information is hidden in the free-text content, therefore participants have simply to read the whole online conversation to make sense of it. This representation formalism is supposed to improve the quality of collective decision making outcome, and more generally, knowledge representation and sharing as it should foster the emergence of more plausible, well-supported and shared conclusions about a given problem.

Using Cohere as a research vehicle, we built on the top of it a number of visual widgets aimed at delivering some types of conversational feedback described in our framework. We chose Cohere as research vehicle on which built the Debate Dashboard for two important reason. First, because it is already able to provide some of our individualized feedback, that is relevance, social network visualization, visibility and community history. This implicates minor effort to make the platform adapted to our aims. Second, Cohere is a web-based asynchronous argument mapping tool, because we want to test if our feedback are able to aid remote, asynchronous mediated conversation and support the grounding process among online users. The asynchronicity makes remote, mediated conversation, as well as the grounding process more complicated. Therefore, the utilization of our feedback in this context makes sense and could be even more appropriated, as well as more challenging.

In the following paragraph, we showed and explained each visual widgets used for providing feedback, its features and how it works.

4.6.2 The Debate Dashboard

The general aim of the Debate Dashboard is to improve argumentation systems' mediation and communication abilities in order support online users' mutual understanding and grounding process. Drawing on grounding cost theory, a set of visual widgets has been developed able to provide users with missing social and conversational feedback. Each visual widget, which compose the Debate Dashboard, has been developed in collaboration with Cohere's research group at Knowledge Media Institute, namely Michelle Bachler, Anna De Liddo and Simon Buckingham Shum. This "augmented" argument mapping tool is available online at http://socialmap.open.ac.uk. In line with individualized and described feedback, in Table 2, we show briefly how each feedback is provided.

As emerged from the table some feedbacks have not been implemented because of the characteristics of the web technology used to implement Cohere; in particular Cohere is not able to work in a synchronous fashion and its upgrade in that direction would have been too costly at this stage of the research.

Table 2. How social and conversational feedback are provided

Affordance	**Visual Widgets**
Profile	User's personal page
Community history	Real time Stats about created ideas
Social Structure	Social network visualization
Copresence	List of users.
Cotemporality	Not provided
Mobility	Not provided
Simultaneity	Not provided
Sequentiality	Not provided
Visibility	Real time Stats about users activity
Contextualization	TagCloud search engine
Relevance	TagCloud
Structuring	Argument map

Figure 8 shows Cohere home page. As it is possible to note, online users can readily have to access to two important feedback, that is *Relevance* (red rectangle) and *Copresence* (green rectangle) feedback.

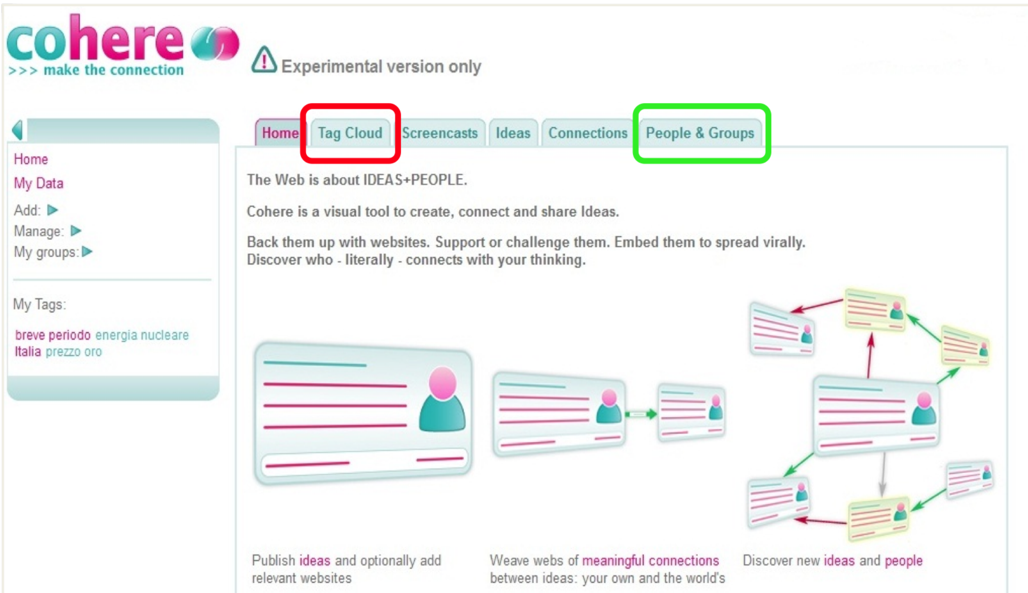


Figure 8. Snapshoot of Cohere's Home page integrated with visual widgets

If users click on *People&Group* button, they can know and visualize who is online. As showed in the Figure 9, a list of users opens where the offline users are indicated by a red circle, while online users are represented by a green circle (Figure 10). This visual representation of *Copresence* feedback is used by the most famous online chat systems, such as Skype or Messenger Instant Messaging. Through this feedback users can know with whom they are speaking and they do not feel “alone” in the virtual environment. In other words, they are aware that they are sharing a virtual space.

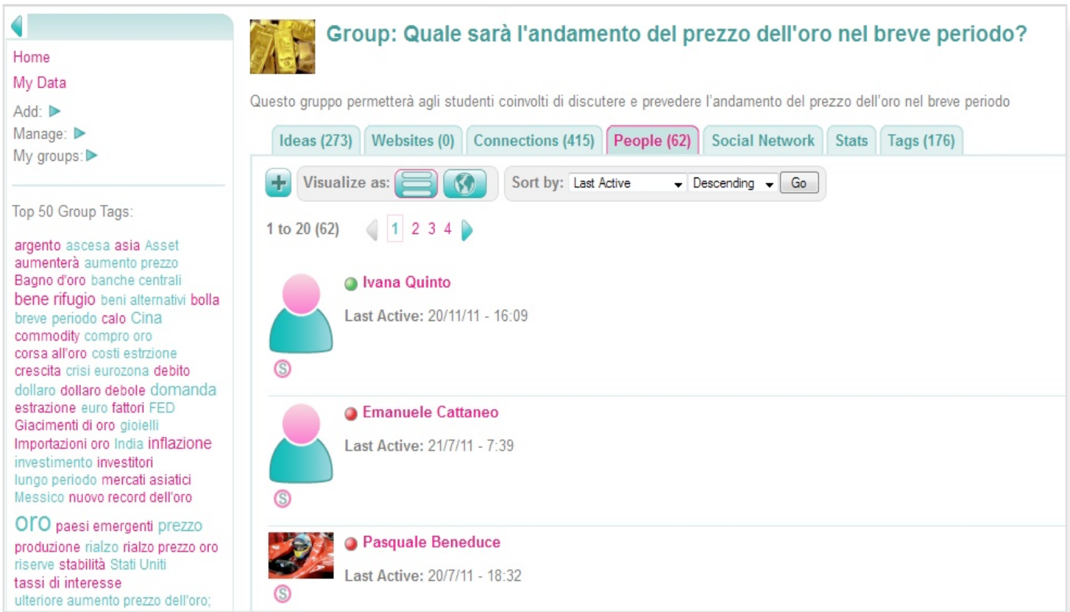


Figure 9. Snapshoot of Cohere …

Users can know who is online with regards both to all community members (Figure 9) and to a specific discussion group (i.e. discussion group on the trend of gold price in the short period – Figure 10). In Figure 10, in reality, only Ivana has green circle. It means that she is online and she is using Cohere.

If users want to visualize other users’ profile and their personal page has to click on users’ name. Users’ personal page opens and it is possible to visualize all information about that users, that is his/her personal information, what and how many group he/she participates in, what ideas and connections he/she creates and his/her social network (Figure 11).

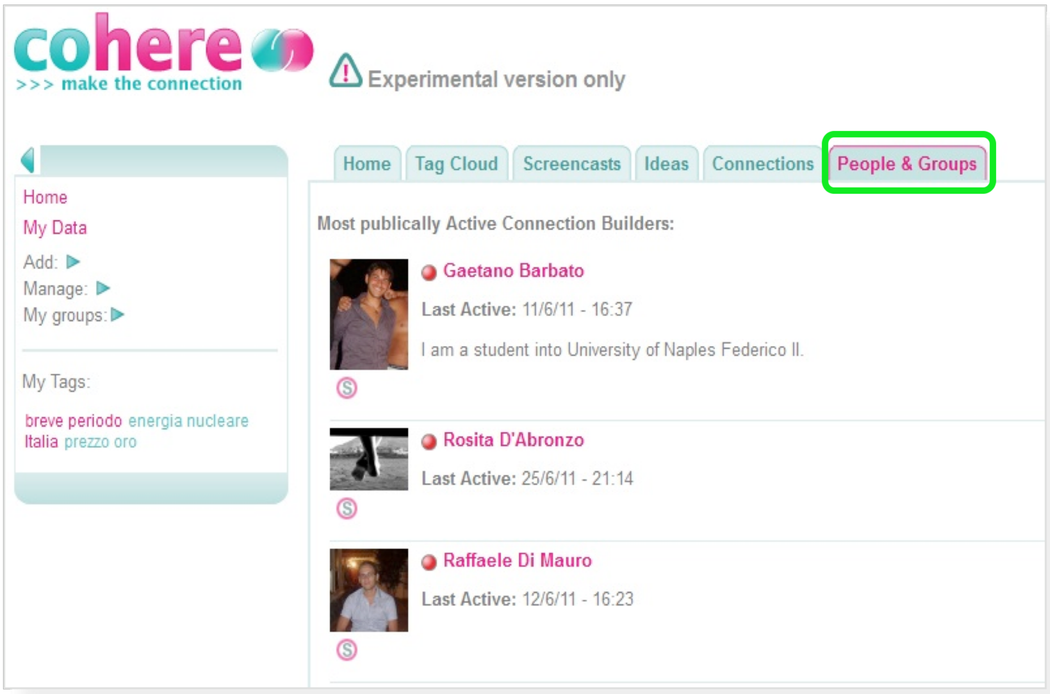


Figure 10. Snapshoot of Cohere *Copresence* feedback (all community)

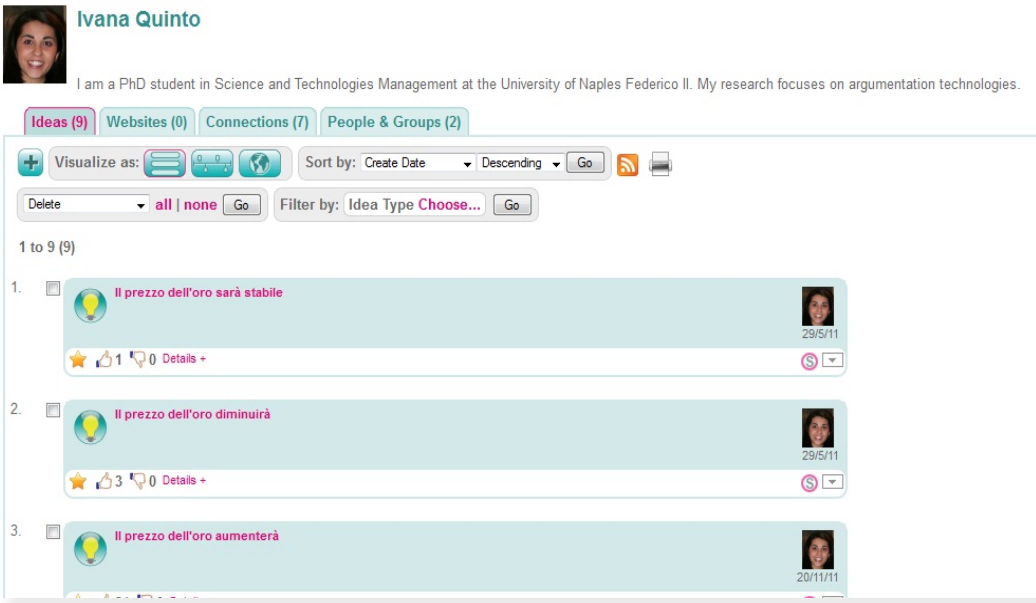


Figure 11. Snapshot of User' personal page (*Profile* feedback)

By using this information, users, not only, learn increasingly about each other, making conversation and common ground building is easier, but, first of all, it allows users to know other community members and recognize them, thus, fostering a sense of community and membership. Sense of membership is a crucial dimension for the success of a virtual community [Kim, 2000].

By clicking on "TagCloud" button on Cohere home page, users can visualize all the TagCloud used by the other online users (Figure 12). The TagCloud enables users to see how frequently words appear in all Cohere mediated conversations. The size of a word depends on the frequency of use of it. The tag are usually single words, normally listed alphabetically, and, as already mentioned, the importance of each tag is shown with font size. This visual format is useful for quickly perceiving the most prominent terms and for locating a term alphabetically to determine its relative prominence. The basic idea is to support users in exploration of an argument maps, especially, when it starts to become too large or aid newcomers in easily making sense about what topic are discussed in Cohere community as they express the interests of community.

Figure 12. Snapshot of Cohere TagCloud (all tags used in Cohere debates)

Cohere is able to provide users with two types of TagCloud visualizations; in other words, users can visualize both all the tags used in Cohere debates (Figure 12) and the top 50 tags used in each discussion group (red rectangular in Figure 13). The representation is compact and draw the eyes towards the largest, and presumably the most important items. Through this representation three important elements are simultaneously represented, that is the words themselves, their relative importance and alphabetical order [Hearst and Rosner, 2008]. Notwithstanding their advantages, TagCloud has a crucial drawback from a perceptual perspective, that is it is difficult to compare all of the tags with a similar size. In order to tackle this problem, we add a features, that is when users roll over the mouse on each tag, they can visualize the frequency of use of that tag.

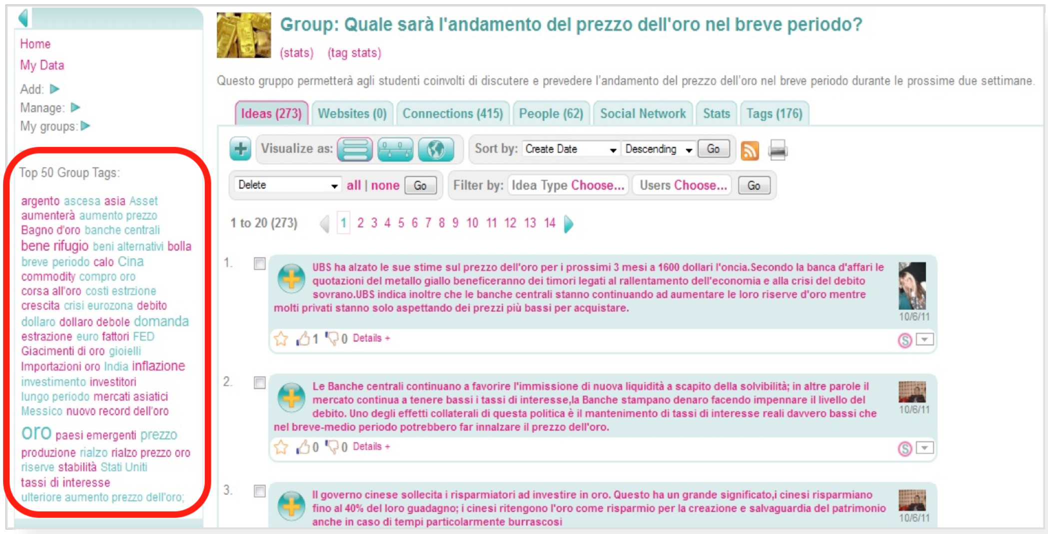


Figure 13. Snapshot of Cohere TagCloud discussion group (*Relevance* feedback)

Additionally, in Cohere TagCloud is used also as a search engine or navigation tool. Indeed, if a user clicks on a tag, all the ideas with that tag are searched and visualized. This could help users to contextualized (Contextualization feedback) the use of that word and better understand the meaning. Another important thing is that, as each idea show its author, users can collect further information about the other users, make comparison among that person's interests and own one's, see what is shared and what diverges. In the Figure 14, for instance, a user clicks on "shelter goods" and the list of ideas contained that tag appears. In this way, the users can know why community speak about it, what is community idea about it, who speaks about it and so on. This feedback helps to grasp numerous information about Community and its discussions, supporting their exploration and analysis.

Figure 14. Snapshot of Cohere TagCloud search engine (*Contextualization* feedback

The last two *Community* feedback that we present are: *Social Network Visualization* (Figure 15) and *Community History* (Figure 16).

By using *Social network visualization,* users can gather several information about discussion group:

- who "speak" to whom: it is indicated by the presence of link
- frequency of relationships: the width of the link represents how much users "speak"
- users' role in the online community: we calculate the degree centrality of each user. Degree centrality is defined as the number of links incident upon a node (i.e., the number of ties that a node has). Dark pink are the most connected users,

while the grey are the slightly connected ones. The most connected users may be the most active and engaged in the discussion.

- kind of relationships: edge colour indicates the type of relationship and it depends on the prevalence of one of three possible links. In other words, if two users mainly support each other ideas and opinions, the link will be green, if they attack each other, the link will be red, it they are neutral respect to their mutual perspectives, the link colour is grey**.** When the link is black means that there is not a strong prevalence.

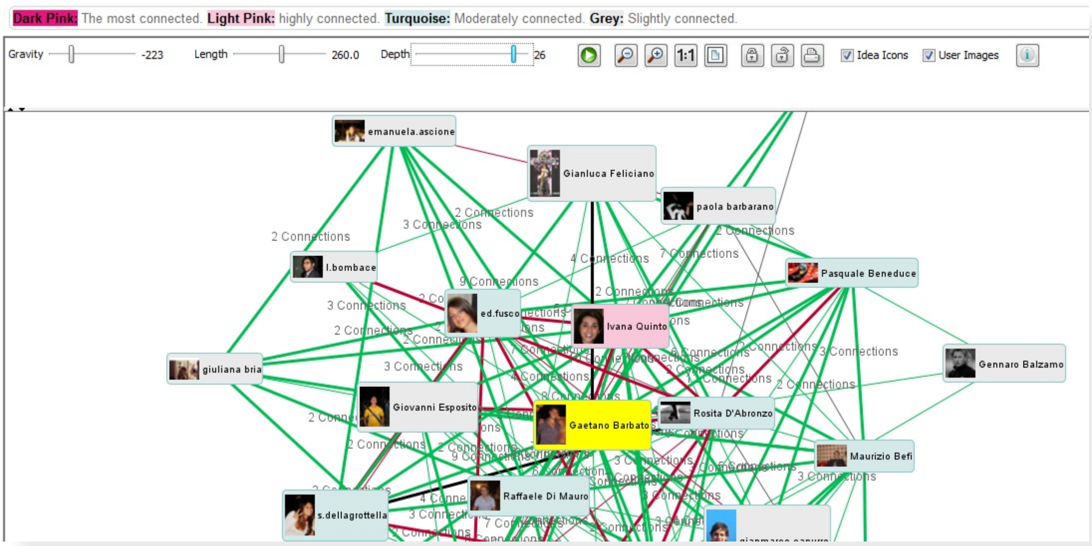


Figure 15. Snapshot Social Network visualization

Through this feedback users can visualize their community and "see" themselves as part of it. This is very important to support the development of a sense of community. Another important elements is that, by knowing user's personal social network, it is possible to understand and know further aspects about the single users by considering all information collect through the other visual widgets as well.

The last *Community* feedback that we present in this research is *Community History*. The aim of this feedback is to provide users with information about level of Community activity in each discussion group (Figure 16). Indeed, users, by clicking on Stats tab (in each discussion group) and then on Ideas button, can visualize different information about generated content. In particular, we provide information about the most connected, recent and popular idea, the type of links and posts created. This feedback provides information about activity and participation level of community as whole and it is supposed to help users understand if Cohere community is lively and push users' participation.

Figure 16. Snapshot *Community history* feedback

Finally, the provision of *Visibility* feedback aims at supporting mutual understanding and building of common ground (Figure 17). Through this feedback, we want to provide users with information about other members' actions relative to the specific discussion or collaborative task. We want to provide a holistic view about users' activity, such as number of posts and connection created about a specific topic. In this way, users' actions are visible to the other community members. In order to access to this information users has to click on Stats tab and then on User button. As showed in the Figure 17, users can know what the most active users are; in other words, it is possible to visualize the list of both the most active connection builders and node builder, as well as the most connected users.

Figure 17. Snapshot *Visibility* feedback

In conclusion, the Debate Dashboard is a web application integrated with an argument mapping tools that provides multiple views of a large dataset. As dataset is updated, the visualizations change to reflect the new data. This Dashboard aims at tracking and representing social and conversational aspects of persistent debates in online communities. Our goal is to set up visualization tools and knowledge maps into a single application that is able to support and improve argumentation technology mediated conversations. Drawing on Grounding costs theory, the Debate Dashboard, by providing three different classes of feedback, tries to, on one hand, support common ground building, improve users' sense-making process and foster a sense of community, and on the other hand, to retain and improve argumentation systems inherent advantages.

In the next Chapter, we present the methodology that we follow to evaluate the Debate Dashboard and its ability to reach the fixed purposes.

Chapter 5
Experiment Design and Methodology

5.1 Introduction

Notwithstanding the several advantages of argumentation technologies in supporting deliberation and decision making process [van Gelder, 2003; Conklin, 2006; Karakapilidis and Tzagarakis, 2007), they seem to be less efficient in mediating and fostering online free interaction and communication. In this study, the focus is the effectiveness and efficiency of argumentation technologies in providing and facilitating online asynchronous communication among remote users. In reality, it is important to note that efficient communication does not ensure successful online distributed deliberation and decision making process given the presence of additional requisites, such as participation of knowledgeable and interested individuals, incentives, etc. In this study, in order to address this problem, in line with communicational theory proposed by Clark and Brennan [1991), we propose to set up a Debate Dashboard able to provide visual social and conversational feedback aims at improving argument-based technologies' communication abilities.

In this Chapter, we present how the Debate Dashboard has been assessed and tested (field experiment), the used instruments to survey and collect data, the methodology used to perform data analysis.

5.2 The Theoretical Model to test

Based on literature review about argumentation technologies, in the Chapter 3 we state the following central research question: "*How to retain the advantages of argument mapping and improve their mediation capability?*"

In order to tackle this problem we propose to develop an augmented argument mapping tool (the Debate Dashboard) able to retain the traditional advantages offered by argumentation technologies and to deliver at the same time a richer set of meta-information aimed at fostering social interaction among users and supporting the construction of mutual understanding. The Debate Dashboard is able to deliver different kinds of meta-information mostly through visual widgets, built upon and connected to the argumentation tool, that are expected to support participant conversations. The basic idea of the Debate Dashboard is to make visible information that in face-to-face conversation is immediately available, while in computer mediated communication are hidden or missing.

In this Chapter, we present the field experiment aiming at testing the effect of the Debate Dashboard, in particular, of visual, social and conversational feedback on mutual understanding, as well as on common ground building and updating. Moreover, in line with as emerged in the literature about the positive effect of mutual understanding on group's coordination, collaboration and performances [Clark, 1996; Convertino *et al.,* 2004; 2008; 2009], we aim at assessing the impact of mutual understanding on group' s performances. In particular, we measure three different dimensions of users' performances, that is: i. Quality of the Outcome (accuracy of decision); ii. Quality of collaboration process (amount of shared and exchanged information, perceptions about collaboration etc) and iii. Usability (ease of use, enjoyment, user satisfaction, perceived usefulness) [Davis, 1989; Venkatesh and Davis, 2003). Another important aspect that we aim at evaluating is the impact of each visual feedback on users' performances. Indeed, numerous researches have analyzed the impact of visual and conversational hidden or missing information on collaboration process, quality of discussion, its outcome, communication and interaction process [Shneirderman, 2000; Erickson *et al.,* 2002; Balakrishnan *et al.,* 2008).

In nutshell, we aim at analyzing the impact of three categories of feedback on mutual understanding and on group's performances; in turn, we want to measure the impact of mutual understanding on users' performances. In Figure 18, we show our theoretical model that we tested through the field experiment that was performed with a community of around 60 students at the University of Naples Federico II.

In the next section, the different hypotheses and the rationale behind them are presented.

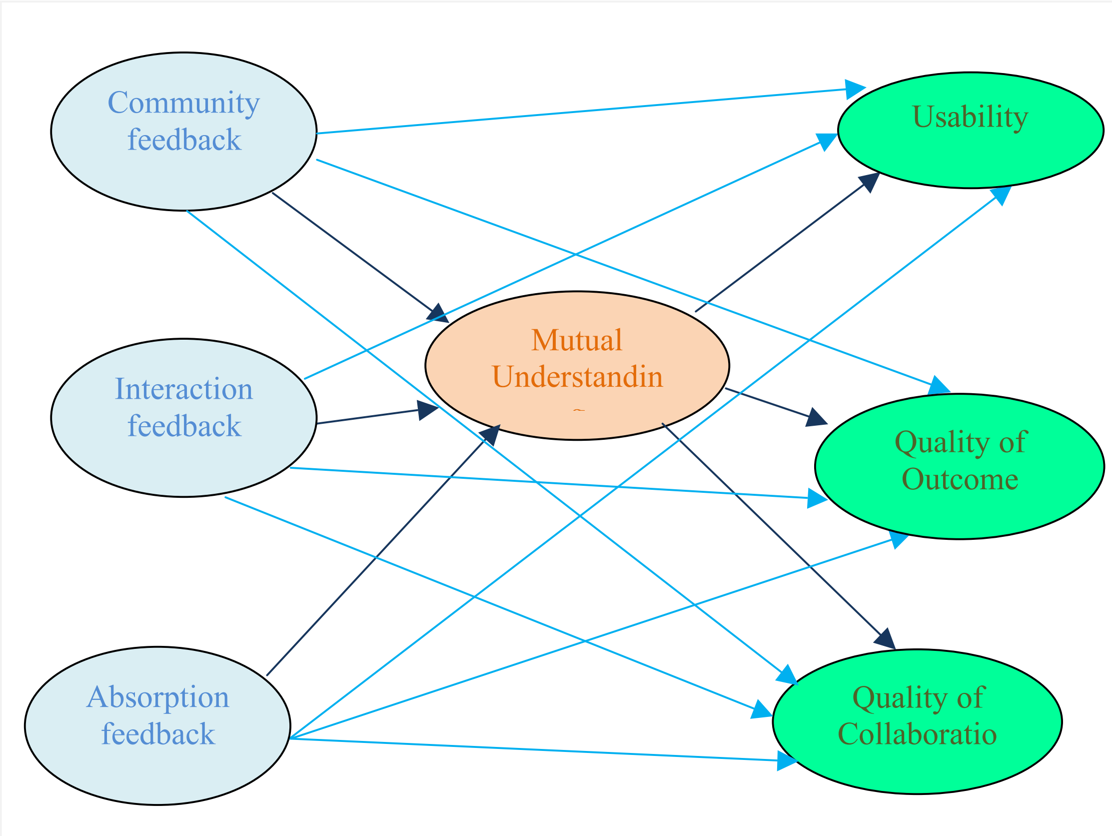


Figure 18. Theoretical model

5.2.1 The Research's Hypotheses

Based on thoroughly literature review presented in Chapters 3 and 4, we defined a set of research hypotheses which have been tested through a field test. The research's hypotheses considered were divided, then, in four blocks to investigate specifically the key components of our framework.

In the model, the use of different categories of feedback is an exogenous variables that is used to explain and predict the increasing of mutual understanding among online remote users. Drawing on Grounding Theory [Clark and Brennan, 1991), the amount of utilization of these classes of feedback is supposed to make simpler mutual understanding and common ground building. In other words, by providing this feedback, we aim at compensating the loss of information that are immediately and easily available in face-to-face conversation. As already discussed, any mediated conversation by a connection technologies is less efficient than face-to-face conversation in supporting grounding process. In addition, the loss of this meta-information hampers free interaction and communication. In the case of argument mapping tools this problem is worsen because of further inherent features of them that additionally hinder free conversations. Therefore, in line with as emerged from the literature, the research hypotheses are:

H1: *Community feedback impact significantly on Mutual Understanding*

H2: *Interaction feedback impact significantly on Mutual Understanding*

H3: *Absorption feedback impact significantly on Mutual Understanding*

The second set of research hypotheses aims at evaluating the impact of mutual understanding on users' performances, that is quality of outcome, quality of online collaboration process and argument mapping tools' usability. Numerous researches have showed that increasing in common ground among participants to conversation results in improvement of group' performances, such as coordination [Clark, 1996), communication, team effectiveness [Convertino *et al.*, 2007), collaboration, quality of decision [Convertino *et al.*, 2008). In other words, common ground is particularly relevant for supporting team of diverse knowledgeable individuals collaborating on decision making and problem solving process [Convertino *et al.*, 2007].

H4: *MU impact significantly on Quality of Collaboration*

H5: *MU impact significantly on Quality of Decision.*

H6: *MU impact significantly on Usability*

In line with the literature that emphasized the effect of provision of hidden and/or lacking information on quality of discussion, users' interaction and quality of the outcome of collaboration process, we try to evaluate the impact of our feedback on users' performances. Indeed, several studies have analyzed the positive impact of visualization tools and, hence, of visual meta-information on users' abilities to perceive new and further information, patterns and trends [Donath *et al.,* 1999], conversation productivity [Erickson *et al.,* 2002], knowledge sharing [Edelson *et al.,* 1996; Ryall *et al.,* 2004], data exploration and navigation [Xiong and Donath, 1999]. Therefore, according to it, the set of research hypotheses is:

H7: *Community feedback impact significantly on Quality of Collaboration*

H8: *Community feedback impact significantly on Quality of Decision*

H9: *Community feedback impact significantly on Usability*

H10: *Interaction feedback impact significantly on Quality of Collaboration*

H11: *Interaction feedback impact significantly on Quality of Decision*

H12: *Interaction feedback impact significantly on Usability*

H13: *Absorption feedback impact significantly on Quality of Collaboration*

H14: *Absorption feedback impact significantly on Quality of Decision*

H15: *Absorption feedback impact significantly on Usability*

Finally, the last set of hypotheses that our research aim at evaluating is about the role of mutual understanding. In other words, according to several researchers, increasing of mutual understanding improves users' performances. In line with this, we think that mutual understanding can have a role of catalyst between visual feedback and users' performances. In other words, we expected that mutual understanding could strengthen the positive effect of visual feedback on users' performances, that is on quality of collaboration, quality of decision and argumentation technologies' s usability.

H16: *Mutual Understanding will mediate the relationships between Community feedback and Quality of Collaboration*

H17: *Mutual Understanding will mediate the relationships between Community feedback and Quality of Decision*

H18: *Mutual Understanding will mediate the relationships between Community feedback and Usability*

H19: *Mutual Understanding will mediate the relationships between Interaction feedback and Quality of Collaboration*

H20: *Mutual Understanding will mediate the relationships between Interaction feedback and Quality of Decision*

H21: *Mutual Understanding will mediate the relationships between Interaction feedback and Usability*

H22: *Mutual Understanding will mediate the relationships between Absorption feedback and Quality of Collaboration*

H23: *Mutual Understanding will mediate the relationships between Absorption feedback and Quality of Decision*

H24: *Mutual Understanding will mediate the relationships between Interaction feedback and Usability*

In Figure 19 we show our theoretical model whit the hypotheses that we want to test by performing a field experiment.

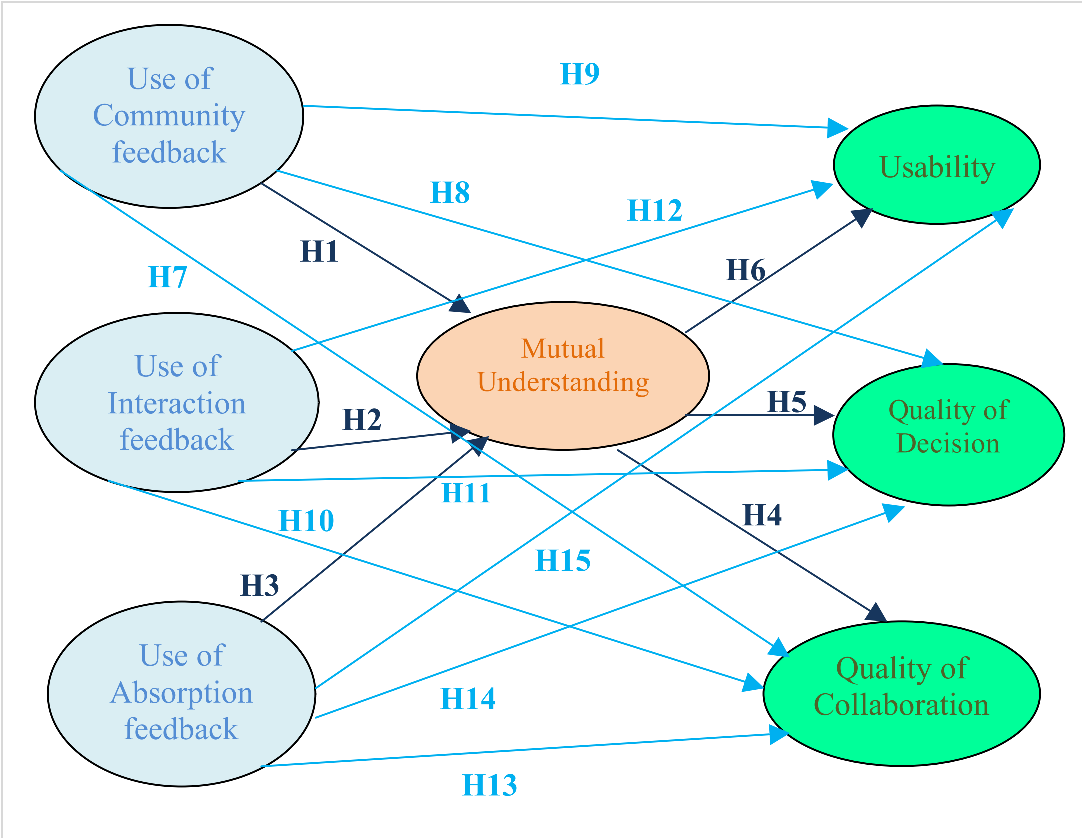


Figure 19. Theoretical model with hypothesis

5.3 Experiment Design: A Field Test

In order to examines the research hypotheses discussed in the previous paragraph, in this section we deal with the field test and each its phase.

A field test has been performed in June of 2011 at the University of Naples Federico II (Italy) with a total community of more than 60 students. Users were graduated students who participated in a single-factor, asynchronous, web-based group decision-making experiment; in other words they were asked to deliberate and forecast the value of two economic variable (more details about the task and the topic of debates will be discussed later in this Chapter). The students were all part of a same class from a graduate program (Economics and Business Organization course) in Industrial Engineering, age 19-22. The participation has been facultative and voluntary and participants to the experiment were compensated with extra academic credits. Inevitably, this led students to feel the experiment as a course task for which they will be evaluated by professor. In addition, students know each other and this could results to some type of social pressures for their fellow students. All these circumstance made the application context different from an open and distributed online community and represent a significant limitation of this research.

As we aim at measuring the impact of the visual feedback on common ground and grounding process, as well as on users' performances, we need to use a between subject experiment design with two different groups. In other words, we need to compare the users' mutual understanding and performances deriving from the utilization of two different argumentation systems, that is one able to provide visual feedback and another that does not provide it. The basic idea behind a between subject experimental approach is that participants can be part of the treatment group or the control group, but cannot be part of both. This type of design is often called an independent measure design because every participant is only subjected to a single treatment. This lowers the chances of participants suffering boredom after a long series of tests or, alternatively, becoming more accomplished through practice and experience, skewing the results. Moreover, this approach has been often used to avoid the carryover effects that can occur in within subjects designs, such as learning, practice and fatigue effects. The problem of this experiment design is that it does not allow to completely control the differences among participants. Notwithstanding, in order to annul the influences of relevant differences between two groups on the results, the treatment and control groups have to be matched or homogenized. To do it, we performed a random assignment of subjects to two conditions (treatment and control group).

In line with experimental requirements, students have been divided in two groups (A and B). Each group used a different version of Cohere platform during the experiment. Indeed, the group A used the so-called "Augmented" Cohere version (http://socialmap.open.ac.uk), that is an argument mapping tool integrated with a set of visual widgets able to provide social and conversational feedback. The group B, instead, used the "Pristine" Cohere version (http://litemap.open.ac.uk), that is an argument mapping technologies without any kind of visual feedback. Both the version has been co-developed with the research group of Knowledge Media Institute, composed of Simon Buckingham Shum, Anna De Liddo and Michelle Bachler. In conclusion, the group A is the Treatment group, while the group B is the control group.

The test developed in five phases:

i. Identification of domain of decision making task

ii. Preparatory work

iii. A two weeks period, in which students were requested to populate the platforms with content and collaboratively make a decision

iv. Follow-up questionnaire

v. Data analysis

The identification of the domain was not so simple, because many different variable should be simultaneously considered. First of all, it should be something along the continuum between a “simple” lab task and a real world problem. On the left side of the continuum we find murder mysteries. On the right side, there is more realistic case such as the diagnosis of a rare disease. As the participants to the experiment are undergraduate students of Economics and Business Organization course, we cannot use too realistic issues given that they requires the involvement of real professionals. Therefore, taking in account this, we considered economic or business problems given that students have the necessary skills and knowledge to work on the task. Additionally, we considered also the following list of general constraints and desiderata to identify the domain:

1. *Independence from the formalism*: the problem should be neutral to the formalism, i.e. no candidate formalism should be clearly better than the others to represent the chosen problem (for instance, argumentation can be a better

formalism to represent "legal reasoning" because of the argumentative tradition present in this domain),

2. *Competence*: the subjects we involve in the study should have the necessary background, skills and motivation to engage in the solution of the problem,

3. *Applicability*: the problem should be as much as possible near to a realistic choice rather than to a fictitious choice problem typically used in lab experiments,

4. *Control*: a solution exists and we have to know it.

5. *Richness and diversity of information*: we need a domain allows students to discuss and confront each other.

6. *Amenable to modelling*: It must be possible to model solutions in the domain with some degree of accuracy.

7. *Attractiveness*: the topic/problem should "attract" the interest of students, otherwise, a possible effect could be a low participation rate. Indeed, as the evaluation test will not be synchronous and in an university lab, we could not control and encourage the participation; therefore, we have to find different motivational lever to stimulate students' participation and involvement.

In accordance to these constraints different possible problems were proposed, such as to forecast the market share of a product or an innovation technology at a given date, i.e. FIAT market share or % of electric/hybrid FIAT cars sold in the short period or % of sold iPAD 2 in America in one month. At the end, the selected problems were economic problems, that is the forecasting of the trend of an economic variable in the short time (three months). In particular, group A has had to forecast the trend of gold price, while the group B has had to forecast the trend of oil price. Both the selected problems respect the above mentioned constraints. Specifically, both problems seem to be independent from the formalism and economic analysis does not seem to be better done with argument mapping tool (1); involved subjects, in part, already have the necessary knowledge and skills because of their University program and, in part, further knowledge and background skills have been taught through the course (2). As we ask users to forecast the trend of an economic variable in the short period, a "right" answer exists. Additionally, numerous information that students can use to support their choice are available and free on the web (http://www.iea.org/, http://www.oecd.org, http://www.gold.org/) (4). In order to favourite the richness and diversity of information, during the Economics course we provided students with additional materials about the specific topic that was selected. Notwithstanding, all the students received the same information and knowledge during the course, we expected a some degree of diversity in knowledge represented in the argument map as it is supposed that the students search and gather further information on the discussion matter (5). Finally, the topic is not intrinsically interesting for students, but motivation can be increased by recognizing some extra points to the students that participate to the experiment for the final exam grade. Finally, we chose two different topics to be assigned to each group of students to avoid any exchange of information among students belonging to different groups as we aim at verifying if, at the end of experiment, the groups achieve different performances.

In the preparatory phase, students had four 2 hours seminars about:

- Collective intelligence and its current applications
- Argumentation theory, with focus on IBIS approach and argument-based technologies
- the Gold and Oil Markets. The students were also given few reading materials and websites about discussion topics to start to gain an overview of them. The articles were taken from newspapers and magazines (i.e. Economist, IlSole24Ore, Times).
- An instructional demo of Cohere.

Additionally, a warm up phase of one week was performed during which users could use and practice with the tool on a different topic. In particular, students discussed on topical argument, that is about the use of nuclear energy and the building of nuclear plant in Italy. We chose this subject because it is controversial, so that community could explore different perspectives and solutions and because it is a topical subject, so that students can easily access to information. During this phase, students can practice and learn to use the argumentation formalism, which, usually, require users to climb a steep learning curve. As the experiment lasted two weeks, we wanted to avoid that students used that period to become quite skilled at using the tool, but we wanted that they focused on the collaborative task and on the discussion.

As already mentioned, two groups (A and B) of students participated in a single-factor, asynchronous, web-based group decision making experiment. Each group worked on a specific collaborative decision making task for two weeks. During these two weeks, the groups developed and worked on a collaborative map that reflects user knowledge, perspectives and opinions, as well as supports collective decision making process on a specific task. In particular, students of group A discussed about and forecasted the trend of Gold Price, while group B debated and predicted the trend of Oil price.

Instead of giving students empty maps, a first level of question and ideas (possible solutions) were provided at the beginning. In particular, the questions were: *What will be the trend of Gold/Oil price in the short period (tree months)?* The possible answers were: i. *The price will tend to increase,* ii. *The price will tend to reduce,* and iii. *The price will be stable.* By using argument mapping tools, users can represent contentious and/or competing point of views in coherent structures made up of alternative positions on an issue at stake with their associated chains of pros and cons arguments.

Finally, the experiment has been run in an asynchronous way in order to: i. respect Cohere features, ii. allow students to incrementally create a map, iii. stimulate participants to externalize all their knowledge, and iv. let users to explore a big enough decision space and therefore make a more accurate and well-supported decision.

At the end of the experiment, all participants completed a follow-up questionnaire (more details in Appendix B) composed of 28 items (7-point Likert scale). We thoroughly present and explain construction process of the questionnaire in the next paragraphs.

5.3.1 Measurements

As discussed in the first section, our theoretical model consists of seven variables, that is: 1) use of Community feedback; 2) use of Interaction feedback; 3) use of Absorption feedback; 4) Mutual Understanding; 5) Quality of online collaboration; 6) Quality of decision; 7) Argument mapping tool Usability. The measurement of this variables is discussed below.

The first three variables concern the use of three different categories of visual, social and conversational feedback that the Debate Dashboard is able to provide. As this feedback are measured and recorded in the same way, in this paragraph henceforth, we refer to these three categories of it by using a more general term, namely **Use of Feedback**. This variable has been measured through the frequency of use. In other words, we aim at knowing whether and how many times students use each categories and, hence, sub-categories of individualized feedback. As already mentioned previously, the research vehicle used in this experiment is Cohere. Unfortunately, Cohere is not able to record and track all users' activity or their exploration and navigation activity , but it can only register when users access to and exit from the systems (log in and log out) and when create a node or a link. Given that we needed to know when students use the feedback, we had to employ a system able to register and track users' browsing in Cohere. In order to do it, we scan and review different systems able to track students' activity, such as web analytics software (i.e. Google Analytics, Yahoo! Web analytics, StatCounter), systems of content-control and screen video capture software (i.e. Camtasia). Each of this system was not suitable respect our aim. In particular, web analytics software provide collected and recorded data in aggregate way, instead we need to know this data for each students. Systems of parental control do not allow to track all different users' activities, but mainly they are web filtering software. Finally, the use of screen video capture software would have required a very long time to view and examine more than 60 videos (because there are more than 60 participants) of several hours. For instance, Camtasia would have allowed a very deeply analysis of users' behaviours that it is not necessary in this phase of the experiment. Additionally, if users had used systems of content control or screen video capture software, at the end of the experiment, they would have had to send us their tracked and recorded information, requiring to the students a further work and making more complicated our data collection.

In line with this, we decided to use a Virtual Machine that was developed by a research group of Universidad Carlos III de Madrid, composed of Abelardo Pardo and Derick Leony. A Virtual Machine is a completely isolated guest operating system installation within a normal host operating system. A Virtual Machine is a software implementation of a machine (i.e. a computer) that executes programs like a physical machine. It provides a complete system platform which supports the execution of a complete operating system (OS). Therefore, students have installed the Virtual Machine on their computers and they used it to work and browse in Cohere. As only group A used the "augmented" Cohere version, we needed to track and recorded only their use of visual feedback; hence, we asked only to participants of group A to install it. All tracked and recorded data are sent and stored to a central server of Universidad Carlos III de Madrid. The Virtual Machine lets to track and register all the URL that users used. For this reason, we asked to Cohere's developers that any feedback was identified by a Web page, that is, by its own URL. This artifice has made possible the counting of individual views, and therefore the quantification of the use of each individual feedback by every user. At the end of the experiment, we had a complete database of all "virtual movements" in Cohere made by the participants during the two weeks and, consequently, has made possible a series of quantitative analysis related to the use of each individual feedback provided.

The most central variable of our theoretical model is **Mutual Understanding**. In literature it is possible to distinguish two main techniques to survey and measure mutual understanding and common ground building, that is through the content analysis or content structural analysis [Beers *et al.,* 2007; Beers *et al.*, 2006; McCarthy *et al.,* 1991; Suthers, 2006] and through post-session questionnaire [Convertino *et al.,* 2005; 2007; 2008; 2009; McCarthy *et al.*, 2001; Monk and Watts, 2000; Whittaker *et al.,* 1998]. Content analysis suffers from several disadvantages, both theoretical and procedural. In particular, content analysis can be extremely time consuming, expensive and laborious, is prone to increased interpretation and subjectivism error, may be often devoid of theoretical base, or attempts liberally to draw meaningful inferences about the relationships and impacts implied in a study, may be inherently reductive, particularly when dealing with complex texts, often disregards the context that produced the text, as well as the state of things after the text is produced [Wimmer and Dominick, 2010]. For these reasons, we decided to use post-session questionnaire to measure and survey mutual understanding and its building over time. Indeed, post-session questionnaire is less time consuming and expensive and reduce possible interpretation error by evaluators. Additionally, we decided to use this survey instrument (questionnaire with 7-point Likert scales) because, in this way, we can use it to measure also the other variables of the model.

Finally, the last variables of model to consider are users' performances, in particular:

- **Quality of online Collaboration**: this variable has been measured through a quantitative measurement, namely number of created connections and through post-session questionnaire (7-point Likert scales). Specifically, we can know the number of created connected by users because Cohere platform is able to record users' activities with regard to the nodes and link creation. As we want to measure the quality of collaboration, we consider, for this variable, only the creation of link among different users' nodes. The creation of link can be considered as a proxy of collaboration, because creation of link may be meant as knowledge exchanged and perspectives and ideas sharing. For this reason, we do not consider link that users create among their own nodes. In particular, we used two measures: Information brokering and Compared thinking. In other words, since connecting is an explicit, reflective act in Cohere, it is straightforward to count how many times students create semantic connections between nodes authored by others (Information brokering). Through these analytics, we can the degree to which users' act as information brokers between others. With reference to Comparing thinking statistic, it counts the connections in which the link author is also author of one of the two connected posts.

- **Quality of Decision*n:*** this variable was measured through 7-point Likert scales and through a quantitative measure, that is the accuracy of students' foresight by comparing groups' decision (i.e. the price will increase, the price will reduce and the price will be stable) and real price.

- **Usability:** this variable was measured by using post-session questionnaire. The items used to measure this construct were mainly adapted by Davis' proposal [1989] and its subsequent modifications. Clearly, the instrument used to capture and measure Cohere's Usability has been contextualized to the study. For this reason, we consider also other similar works for defining the related items [Venkatesh and Davis, 2000; Vassileva and Sun, 2007, Convertino *et al.*, 2007; Daily- Jones *et al.,* 1998; Venkatesh, 2000].

According to as emerged in this paragraph, therefore, we used three different database to test our hypotheses, in particular:

1. *Cohere database*. It includes all data regarding users' activities performed on Cohere platforms (group A and group B).

2. *Post-session questionnaire database*. It includes data collected through the follow up questionnaire administered to all participants at the end of the experiment (group A and group B).

3. *Virtual Machine database*. This database contains only data related to students of Group A. By using the virtual machine, the use of each feedback has been tracked and recorded through their respective URLs. It was possible, because each visual widget, by which we provide different individualized feedback, has an own web page and, thus, an URL.

5.3.2 Post-session Questionnaire

A survey instrument was used to collect data in this research. A survey is a means of gathering data and information about the characteristics, opinions and attitudes of a group of individuals [Tanur, 1982]. In particular, we developed a post-session questionnaire which was administrated to all participants at the end of the two weeks during which users worked, collaborated and discussed about their decision making tasks by using Cohere. Through the questionnaire the four latent constructs were investigated. Each construct measures one variable of theoretical model, namely **Mutual Understanding**, **Quality of online collaboration**, **Quality of Decision**, **Cohere's Usability**.

The questionnaire is composed of 28 items grouped in clusters, one for each of the measures mentioned above. A Likert scale is a type of psychometric response scale often used to obtain participant's preferences or degree of agreement with a statement. In particular, respondents have to indicate their level of agreement with a given statement by using an ordinal scale. The point scale ranges from "Strongly disagree" to "Strongly disagree". Most commonly used is a 5-point scale, but we use a 7-point scales to add additional granularity.

The items of each construct have been defined on the basis of literature on common ground building in mediated conversation, online collaboration and Technology Acceptance Model. In particular, Table 3 describes the 28 questionnaire items, the 4 clusters and the sources for each cluster. As showed in the table, the Quality of online collaboration and the Mutual Understanding are measured both by 9 items (respectively Q1-Q9 and Q14-Q22), Quality of Decision by 4 items (Q10-Q13) and Usability by (Q23-28).

Table 3. Questionnaire items, Constructs and main sources

#	Questionnaire items	Constructs	Sources
Q1	The interaction level developed during Cohere-mediated conversation was satisfying	**Quality of online Collaboration (QofC)**	Sellen *et al.,* 1992 Vandergriff, 2006 Adapted from: Daily-Jones *et al.*, 1998.
Q2	I found the online discussion interesting and engaging		
Q3	Collaboration was effective to solve assigned problem		
Q4	I found it difficult to keep track of the conversation		
Q5	The argument map was helpful in facilitating knowledge sharing among team members		
Q6	I shared my own knowledge about the task with my teammates		
Q7	I found that my teammates have shared own their knowledge about the task		
Q8	The group developed a good amount of work		
Q9	The group made a good job		
Q10	I think that, at the end of online debate, the group has a common position about the discussion topic	**Quality of Decision (QofD)**	Convertino *et al.*, 2007 Vandergriff, 2006.
Q11	What is your initial decision before discussing with other group members?		
Q12	What is your decision at the end of online debate?		
Q13	What is group' s decision at the end of the discussion?		
Q14	In general, I have not had problems to understand the meaning of other team members' posts	**Mutual Understanding (MU)**	Monk and Watts, 2000 Whittaker *et al.*, 1998 Adapted from Convertino *et al.,* 2004; 2007; 2008; 2009 McCarthy *et al.*, 2001
Q15	In general, I think that the other team members have understood my contributions without difficulty		
Q16	I could easily understand (tell) what my teammates had done on Cohere		
Q17	I could easily understand who has done what		
Q18	I could easily say who is online on Cohere		
Q19	My teammates and I developed better understanding about each other over the two weeks		
Q20	My teammates and I developed shared understanding about the task over the time		
Q21	I found online conversation is often redundant		
Q22	I found there are many irrelevant posts respect the assigned task		
Q23	Interaction with the system does not require a lot of my mental effort	**Usability (Usab)**	Venkatesh and Davis, 2000 Vassileva and Sun, 2007 Convertino *et al.*, 2007 Daily-Jones *et al.,* 1998 Venkatesh, 2000
Q24	I find the system to be easy to use		
Q25	I enjoyed collaborating with my teammates using Cohere		
Q26	I would enjoy working with my teammates again using Cohere		
Q27	It was easy to communicate effectively given the tools available		
Q28	Cohere supports and facilitates collaboration among online users		

5.4 Data Analysis Methodology

This research makes use of Structural Equation Modelling (henceforth SEM) to analyze the theoretical model presented in the previous paragraphs. SEMs are "*multivariate techniques combining aspects of multiple regression (examining dependence relationships) and factor analysis (representing unmeasured concepts with multiple variables) to estimate a series of interrelated dependence relationships simultaneously*" [Gefen *et al.*, 2000, p. 72]. SEM has several advantages over first generation techniques like principle components analysis, factor analysis, discriminant analysis, and multiple regression. First, SEM allows researchers to model relationships among multiple predictor and criterion variables [Chin, 1998]. Second, SEM lets to examine a series of dependence relationships simultaneously. In other words, a hypothesized dependent variable can become independent variables in a subsequent dependence relationship. Instead, the main multivariate regression allow to examine only single relationship at a time [Hair *et al.*, 2006]. Third, SEM enables researchers to measure latent (unobservable) variables. Finally, SEM allows researchers to assess the measurement models and structural models simultaneously. Thus, measurement errors can be analyzed as part of the model. These attributes enable researchers to answer a set of interrelated research questions in a single, systematic, comprehensive analysis [Gefen *et al.*, 2000]. Consequently, SEM is well suited to modelling complex processes [Gefen *et al.*, 2000] such as common ground building. Researchers have two methods of SEM analysis to choose from. Researchers can use covariance-based SEM or they can use partial least squares-based SEM. PLS was chosen over covariance-based SEM because PLS supports exploratory research and the data distribution assumptions of PLS are less stringent than the assumptions behind covariance-based SEM [Anderson and Gerbing, 1988]. Also, PLS is capable of assessing indirect effects such as the ones in hypotheses H16-H24 [Chin *et al.,* 2003].

SEMs [Bollen, 1989; Kaplan, 2000] include a number of statistical methods that allow to estimate the relationships, as defined in a theoretical model, which connect two or more latent complex concepts (latent constructs), measured by a number of observed variables (manifest variables). They represent a point of union between *exploratory* *factor analysis* [Thurstone, 1931] and the *path analysis* [Tukey, 1964; Alwin and Hauser, 1975].

Path models are considered a logical extension of the regression models because they involve the analysis of simultaneous multiple regression equations. Indeed, while a path model is a relational model with direct and indirect effects between the observed variables, multivariate multiple regression models take into account only the direct relationships between independent variables and the dependent variables.
In SEM, when variables within model are latent, and therefore measured by manifest variables, the path analysis [Wright, 1934] aims at computing the impact of each manifest variable on latent ones through the so-called path coefficients.

As already mentioned, in this research, we used Partial Least Square Path Modeling (PLS-PM) or Partial Least Square approach to SEM (SEM PLS). This method was developed as a flexible technique for the treatment of a vast amount of data characterized by missing values , highly correlated variables and small sample size compared to the number of variables. These structural equation models were born to be initially applied to the metric variables, which are characterized by the existence of a unit (or account), then they were then applied to well-defined ordinal variables as well.
SEM techniques can be seen as the result of two research area, an econometric perspective, whose main focus is on prediction, and a psychometric perspective, whose theoretical constructs are latent variables (unobserved) that are indirectly estimated from the observed measurements or manifest variables.

The constituent unit of a structural equation model is the regression equation (in the SEM is defined structural equation) and expresses, through the mathematical formalization, the relationship between a dependent variable and several independent variables.
By a mathematical view, the structural equation models can be explained through a set of systems of linear equations (1), each of which represents a causal link among variables. In other words, they are a set of causal relationships among variables, formalized, as a whole, through a system of algebraic equations, one for each dependent

variable, where the latter is expressed as a function of the independent variables that affect it:

$$x_1 = b_{12}x_2 + b_{13}x_3 + \ \ldots..+b_{1k}x_k + e_1$$

$$x_2 = b_{21}x_1 + b_{23}x_3 + \ \ldots..+b_{2k}x_k + e_2$$

•

•

•

•

$$x_k = b_{k1}x_1 + b_{k2}x_2 + \ \ldots..+b_{kk-1}x_{k-1} + e_k \qquad (1)$$

Each of these equations expresses the relationship between a dependent variable (target of a one-way arrow) and a number of other variables. The right side of equation is made up of the independent variables that affect and explain the dependent variable (left side) and b coefficient, whose value say how much the dependent variables depends on each of independent ones. The second member of the equation is hence given by the sum of its parts as there are variables which act on the dependent variable contained in the first member of equation. Each element of right side of equation is the result of the product of each independent variable (i.e. in the graph is the starting point of the arrow) for the these summands that are made by the product of each independent variable (starting point of the arrow) for the coefficient associated to the relationship (i.e. in the graph the relationship is represented by the arrow). In addition, as a final elements, it should be added to the stochastic error. The equations are as many as the dependent variables. This approach is the only truly appropriated to provide a representation of complex real processes, although it is a simplified model. In fact, it takes into account not only the multiplicity of causes (independent variables) that act on a dependent variable (multivariate analysis), but also the connections among the different causes. The real processes should be interpreted as a complex network of relations among variables; one of the strengthens of this approach is just the possibility to define the structure of this network by using systems of equations (for this reason, Structural Equation Modelling).

As consequence, each equation of system is called structural equation and b coefficients are defined structural parameters. One of the reason that encouraged us to use this statistical model to evaluate and test the research hypotheses is that the variables can be, in the same structural equation model, both dependent and independent, that the independent variable in an equation can be dependent in another. By using econometric terminology, we should use exogenous and endogenous terms to indicate the variables, where the first are those outside the model, and therefore, can only act as independent variables, while endogenous variables, being internal to the model, can, alternatively, be, in different equations, dependent or independent variables (in any case, the endogenous variables has at least to be dependent in an equation). The exogenous variables are also called pre-determined variables, to underline the fact that their value is determined outside the system of equations (not explained by the model) and do not depend on internal variable to the model or errors.

The structure of a structural equation model is defined by: i. the coefficients b, ii. variances and co-variances of exogenous variables (X) and iii. the error variance and covariance (e). The structural parameters, that express the strength of causal relationships between variables, are divided into coefficients γ and coefficients β; this distinction depends on whether they relate to causal links from exogenous variables (marked with X) or endogenous (marked with the Y). The coefficients γ and β define the structure of relations between the different endogenous variables (Y) and between X and Y. In addition, while variances and co-variances of exogenous variables define the structure of relations among them, variances and co-variances of error define the structure of relations among them:

$$Y_1 = X_1 + X_2 + e_1$$

$$Y_2 = \beta_{21} Y_1 + \gamma_{21} X_1 + \gamma_{22} X_2 + e_2$$

The graphical representation of the structural equation models uses the same symbols introduced by path analysis. The criteria that govern the graphical representation of a structural equation model are the following:

- The latent variables, also known as theoretical constructs are used to represent those aspects of a phenomenon that cannot be directly measured. These variables can be either exogenous, if independent in the whole system of equations representing the model, or endogenous, if at least dependent from an equation and are represented by a circle or ellipse;

- The manifest variables, which correspond to the measurable aspects of a phenomenon, which are usually detected by a questionnaire, are represented by a square or rectangle;

- The direct relationship between two variables is indicated with a pointing arrow that is directed from independent variable (cause) to dependent variable (effect).

Each SEM is made up of two sub-models: Structural Model (or Inner Model) and Measurement Model (or Outer Model).

Structural Model is a set of one or more dependence relationship linking the hypotheses model's construct. The structural model is most useful in representing the interrelationship of variables between constructs. In this case, the parameters to estimate are the path coefficients (βij), i.e. the regression coefficients connecting the latent variables to each other (representing the relationships among latent variables), and the error terms for any regression in the structural model. The structural model underlying the structural equation model is:

$$\eta = B\eta + \Gamma\xi + \zeta$$

where η is the vector of latent variables endogenous, ξ is the vector of latent variables exogenous; B is the matrix of structural coefficients between the endogenous variables; Γ is the matrix of structural coefficients between endogenous and exogenous variables, and finally ζ identifies the vector of residuals, i.e. the errors of the estimation model. The vectors η and ζ contain m elements (ie how many are the endogenous variables η), the vector ξ contains n elements (as there are exogenous variables ξ). The matrix B contains m*m elements, i.e. a square matrix of dimension equal to the number of endogenous variables η. In addition, its diagonal is always made up of all 0, since they correspond to the regression coefficients of each variable with itself. The matrix Γ is instead of order m*n, where n is the number of exogenous variables.

The measurement model specifies the indicators for each construct and enables an assessment of construct validity. In other words, it is the specification of measurement theory that shows how constructs are operationalized by set of measured variables. Therefore, it defines the relationships between the latent variables and their observed indicators, namely the corresponding manifest variables (since we assume that η and ξ are measured by indicators observed). It is formulated as follows:

$$Y = \Lambda_y \eta + \varepsilon$$

$$X = \Lambda_x \xi + \delta$$

The first equation expresses the measurement model the relationship between the endogenous latent variables and observed variables. In this equation, Y represents the vector of endogenous observed variables, η represents the vector of endogenous latent, and ε the vector of errors. The vectors Y and ε contain p elements (as many as the observed variables Y), the vector η contains m elements (as many as are the latent variables η). The matrix of structural coefficients between the observed variables and latent variables (that is the matrix of regression coefficients of η on Y), represented by the symbol Λy in the equation, contains p*m elements.

The second equation expresses the relationship between the observed and latent exogenous variables. In this equation, X represent the vectors of observed exogenous variables, ξ represent the vector of latent exogenous variable and δ is the vector of latent exogenous variables errors. The vector X and δ are made up of q elements (number of observed exogenous variables X), while the vector ξ is composed of n elements (as there are latent exogenous variable). The matrix of structural coefficients between the observed and latent variables (the matrix of regression coefficients of ξ on X) is indicated through Λx and it is of order q*n.

In the SEM, two different types of measurement model exist, namely formative and reflective model (Figure 20).

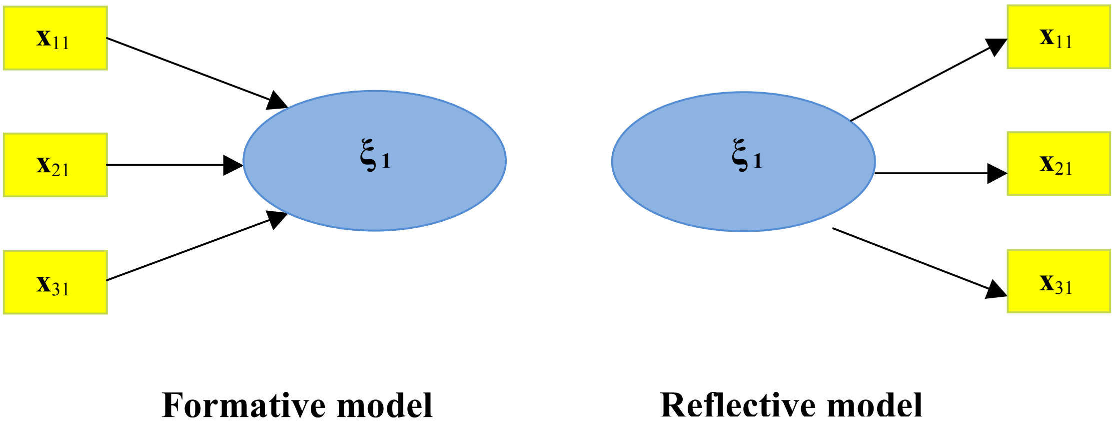


Figure 20: Formative and Reflective measurement models

A formative measurement theory is modeled based on the assumption that the measured variables cause the latent construct. In this case, we assumes that the direction of the causal relationship is the opposite, namely that the measures are to cause the construct, so the set of indicators jointly determine the meaning of the construct [Bollen and Lennox, 1991; Diamantopoulos and Winklhofer, 2001; Jarvis *et al.*, 2003]. The choice between a formative model rather than reflective depends on the causal priority between the indicator and the construct. The causal structures linking constructs to measures can be also characterized by the presence of direct and indirect effects and can be regarded as spurious when it finds one or more common causes and measures to construct. In contrast, a reflective measurement theory is based on the idea that latent constructs cause the measured variables. In order words, we assume that the underlying construct causes the observed variables (i.e. the empirical indicators) and, therefore, variations in the construct cause changes in the measures. For this reason, the measures reflect or are a manifestation of the construct. Thus the arrow are draw from latent construct to measured variables.

Chapter 6
Data Analysis and Results

6.1 Introduction

In order to test the research hypotheses presented and explained in the Chapter 5, we performed a field test in June 2011 at the University of Naples with a community of 64 undergraduate students. The basic idea is to predict and evaluate the impact of visual, social and conversational feedback, provided students with visual widgets, on Mutual Understanding and, in turn, the impact of Mutual Understanding on users' performances. Furthermore, in line with as emerged from literature on visualization tools, we aim at assessing the impact of visual widgets directly on the users' performances. In Figure 21 a very simplified version of theoretical model to test is showed.

Legend:

P	Performance
MU	Mutual understanding
F	Feedback
←	Affect positively

Figure 21. Simplified Theoretical Model

As showed in the model, the Mutual Understanding is both variable dependent on the feedback and independent with regard to performance. It is important to highlight the fact that it has been evaluated also the mediation effect of Mutual Understanding on users' performances, namely Quality of Online Collaboration, Quality of Decision and

Usability. Indeed, we expect that greater amount of common ground results in better users' performances.

The data for this research were collected by using two experimental version of Cohere platforms (users' activity and level of participation), post-session questionnaire (users' perceptions about mutual understanding and the level of users' performances) and a Virtual Machine (to track and record the use of visual feedback of students group A). For this reason, we analyzed the data of three different database for each of survey instrument used.

In this Chapter, we present and show the data analysis performed and the obtained results. Two different software were used to undertake the examination, namely SPSS 17.0 and SmartPLS[1]. SPSS (Statistical Package for the Social Sciences) is among the most widely used programs for statistical analysis in social science. We used SPSS to compute some descriptive statistics, t-tests, coefficient of reliability for Likert scales (Cronbach's alpha), normality tests. Instead, SmartPLS is a software application that enables users to perform path modelling with latent variables using the partial least square (Ringle *et al.,* 2005). SmartPLS was developed by a team from the University of Hamburg School of Business.

6.2 Descriptive statistics

A field test, to evaluate the impact of the use of Debate Dashboard on the grounding process and on users' performances, was performed in June 2011 at the University of Naples with a community of 64 undergraduate students. The students were all part of a same class from a graduate program in Industrial Engineering, age 19-22. Students participated in a single-factor, asynchronous, web-based group decision-making experiment.

[1] Smart PLS is available for free download at http://www.smartpls.de/forum

The participation was facultative and voluntary. At the beginning, students that decide to participate were 123 (Table 4).

Table 4. Demographic statistics for gender of initial population

Sex	Frequency	Percentage
Male	74	60%
Female	49	40%
Total	123	100%

These students were randomly assigned to the two groups (A and B), in order to ensure internal validity [van den Braak *et al.,* 2006]. We used RAND Excel formula to assign automatically and casually a number x between 0 and 1 to each student; then by using a if-then Excel function we divided all participants in two groups. In particular:

- for $0 < x \leq 0{,}5$ students have been add to the group A,
- for $0{,}6 \leq x \leq 1$ students have been add to the group B.

In order to verify that there were no differences between two groups, a t-test was performed. We used an academic proficiency indicator to test the uniformity of two groups and, thus, to avoid to have groups with different characteristics that could lead to invalidate the obtained results. The formula to calculate this academic proficiency indicator is:

$$\frac{(Average\ marks \times N^{\circ}\ of\ passed\ exams)}{year\ of\ study}$$

After randomization process, the two groups was made up respectively of 59 (group A) and 64 (group B). Table 5 shows the mean and standard deviation of both groups.

The results of T-test show that the difference between two groups are not significant; indeed, $t_{calculated}$ is equal to 0.16, less than critical t value (1.658) (df=121; α=.05).

Table 5. Descriptive statistics on students' University Performance Indicator

Group	N	Mean	Std. Deviation
A	59	81,88	26,39
B	64	75,70	29,66

During warm up phase, numerous students gave up the experiment. Therefore, at the end of this preliminary phase the groups were respectively composed of 34 (group A) and 42 (group B). Before starting the experimental phase, other students decide to not participate, that is 9 for group A and 3 for group B. Therefore, before starting the experiment, the two groups was so composed: the treatment group (group A) had 25 students and the control group (B) has 39 students. Table 6 and Table 7 show statistics about participants' gender and year of study per group.

Table 6. Demographic statistics for gender of Group A and Group B

Sex	Group A	Group B
Male	14 (56%)	25 (64%)
Female	11 (44%)	14 (36%)
Total	25	39

Table 7. Statistics for year of study

Year of study	Group A	Group B
Second	21 (84%)	35 (89%)
Third	4 (16%)	4 (11%)
Total	25	39

In the following paragraph, we present the data analysis performed and the obtained results per each of used database, namely Cohere database, post-session questionnaire database and virtual machine database. Finally, SEM results will be showed.

6.3 Data Analysis of Cohere Database

Cohere is web-based argumentation tool which lets users to create argument maps reflecting their opinions, knowledge and ideas. In general, argument mapping tools not only allow participants to contribute to the conversation by adding posts (node), but also to make semantic connections between them. Participants can explicitly connect their posts to the posts which is relevant or pertinent to what they want to say. The connection between posts explains the rhetorical move users want to make in the conversation. By using Cohere database, we analyzed users' activity and participation level of both groups in order to start to explore the ability of visual, social and conversational feedback to improve users' performances. The basic idea is that the users of the" augmented" platform, thanks to the availability of feedbacks, would increase their level of mutual understanding and experience a more efficient deliberation. In other words, by making argument mapping-mediated conversation easier and more efficient, users' performance should improve in term of efficiency. In this case, users' performances are measured assessing users' activity in Cohere. As already mentioned, Cohere lets users to participate conversation by creating posts and links. For this reason, we measure users' activity on the basis of the total connections and posts created by each of them. In other words, user's contributions indicates the sum of posts and connections created by each user.

Let's start with some data elaboration in order to better analyze the utilization of Cohere and users' participation. During the experiment, Cohere was active 24 hours per day and we can observe a high level of user participation in both the groups over time (Figure 22). The users in the treatment group contributed significantly more than users in the control group on a day-to-day basis except at the end of the experiment. This data shows that probably the users of the augmented platform did not experience any particular difficulty associable to the use of a richer and potentially more difficult to use tool.

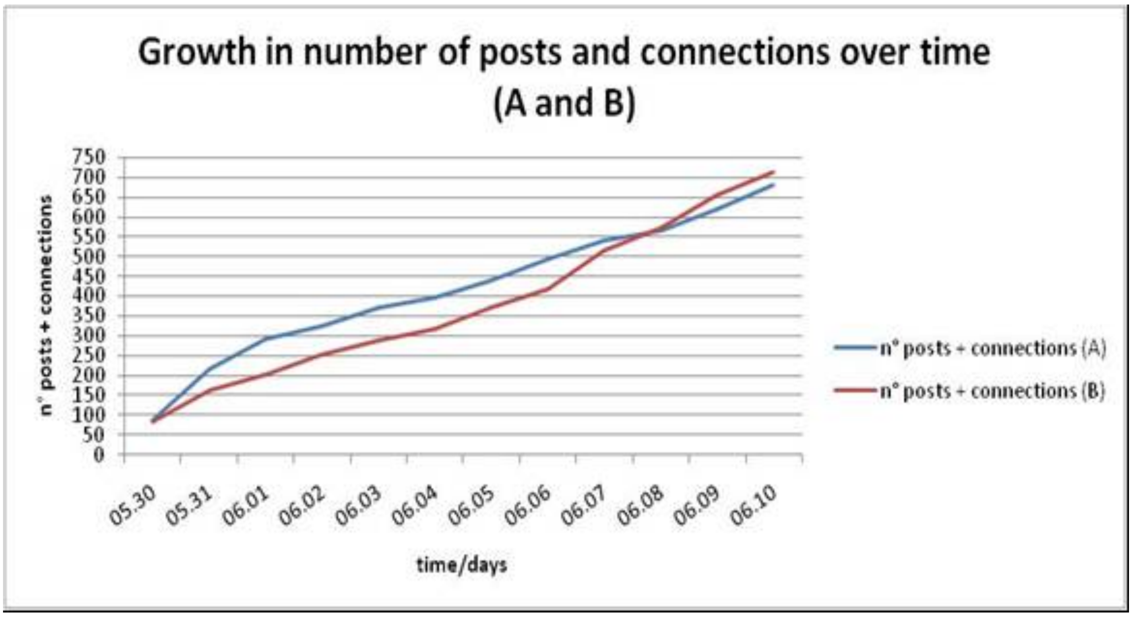


Figure 22. Growth in number of posts and connections over time

As showed in the next figures, the intensity of participation varied widely among users (Figures 23 and 24), roughly following the power law distribution that has been found to be typical of most online community [Wilkinson, 2008].

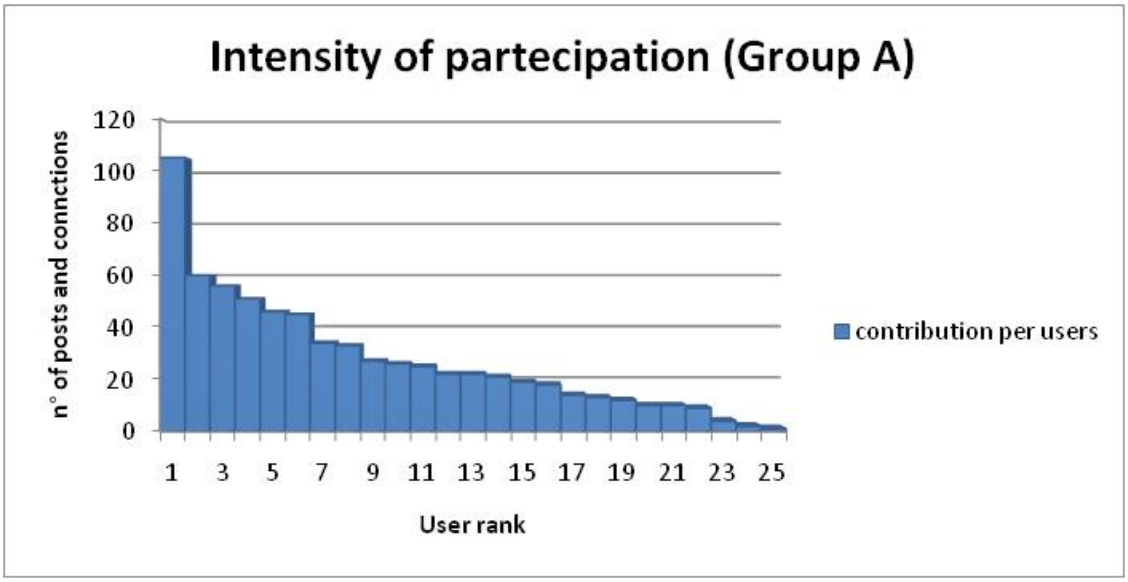


Figure 23. Distribution of numbers of post and connections per users (Group A)

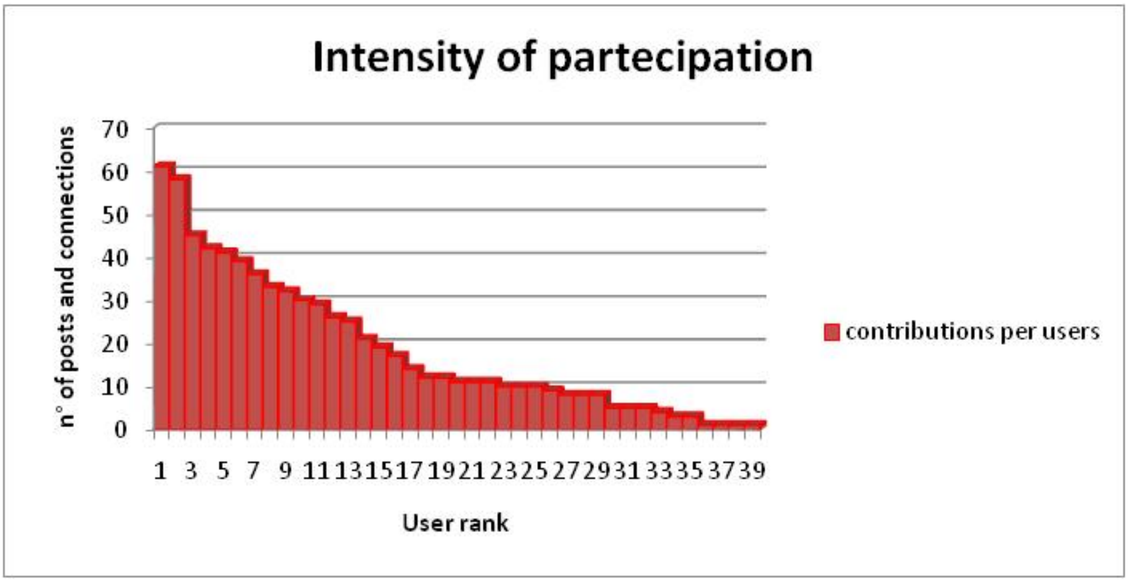


Figure 24. Distribution of numbers of post and connections per users (Group B)

This data confirms what has emerged from previous studies [Wilkinson, 1998] on how people contribute to peer production, i.e. a few very active users account for the most of contributions. While this pattern is common to both groups, the members of the Debate Dashboard group were more active and in this group there was a higher proportion of power users (24% of users with more than 40 contributions Vs 13% in the control group).

Overall, in two weeks the online community posted 603 posts and created 792 connections. The following tables show the number of posts per each group (Table 8), the number of connection per group (Table 9) and the grand totals of created posts and connections for each group (Table 10).

Table 8. Descriptive statistics on users' actvity

Post	Group A	Group B
# created post	269	334
Average number of post	10,76	8,56
St. deviation	5,72	7,34

Table 9. Descriptive statistics on users' activity

Connection	Group A	Group B
# created connection	412	380
Average number of connection	16,48	9,74
St. deviation	20,12	10,05

Table 10. Descriptive statistics on users' activity

User's activity – Group A		User's activity – Group B	
# Posts	269	# Posts	334
# Connections	412	# Connections	380
Total	681	Total	714
Average	27,24	Average	18,31
St. Deviation	22,98	St. Deviation	16,28

Since group A is smaller than group B (respectively 25 and 39), as showed in Tables 8-10, it results to be more active. Indeed, on average, the users of group A have participated to the discussion with more contributions, namely around 27 per users versus 18 contributions per user of group B. Another important statistic to consider is the standard deviation. In both groups, there is a high standard deviation. It remarks what is emerged from the Figures 23 and 24, that there is a small number of users that created the most part of contributions (posts and connections). Moreover, by examining Tables 8-10, it is possible to note that the group A had a more collaborative approach to the discussions; this emerge from the analysis of the number of connections created which is higher than one of group B (respectively, 412 and 380).

The following figures compare the two groups on the basis of post type (Figure 25) and links type (Figure 26) used by both groups. In particular, users could use only 4 posts type among all those proposed by Cohere, namely *Question, Idea, Pro* (ideas that support other users' posts) and *Con* (ideas that attack other users' posts). Whit regard to link type, users could use only *supports*, *against* and *respond to* typologies. As showed, group B seems to have had a more controversial discussion, indeed, the number of *Con* posts and *Attack* links is higher than in group A. Additionally, group A did not make errors in post and link type choice. Likely, this may depends on the greater visibility on others groups members' activity and work that helps and guides users in collaborative discussion process and, thus, in a better group's performance.

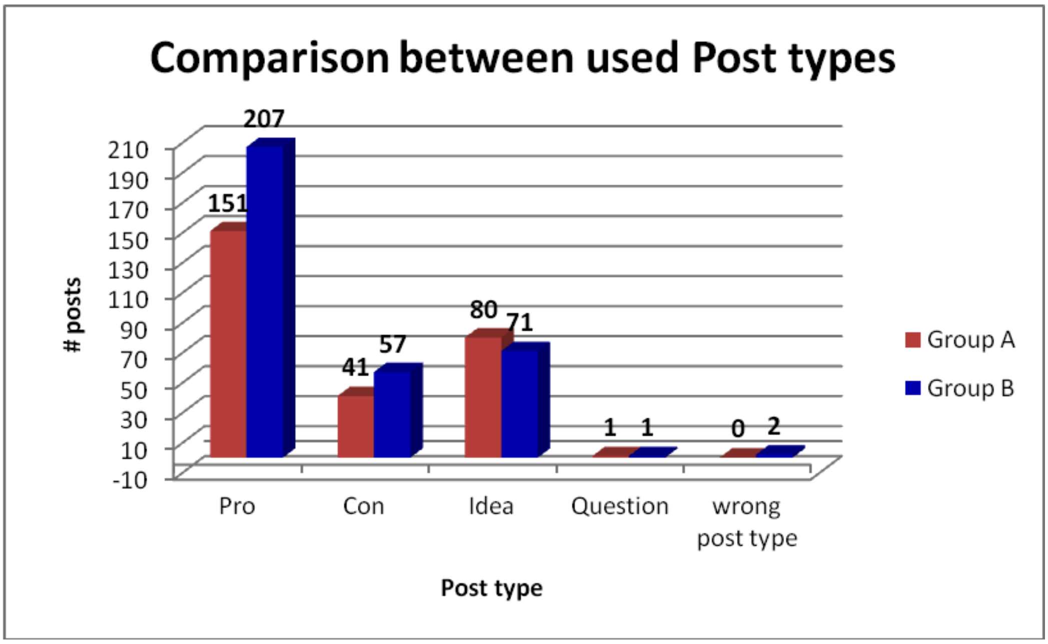


Figure 25. Comparison between Group A's and Group B's used posts type

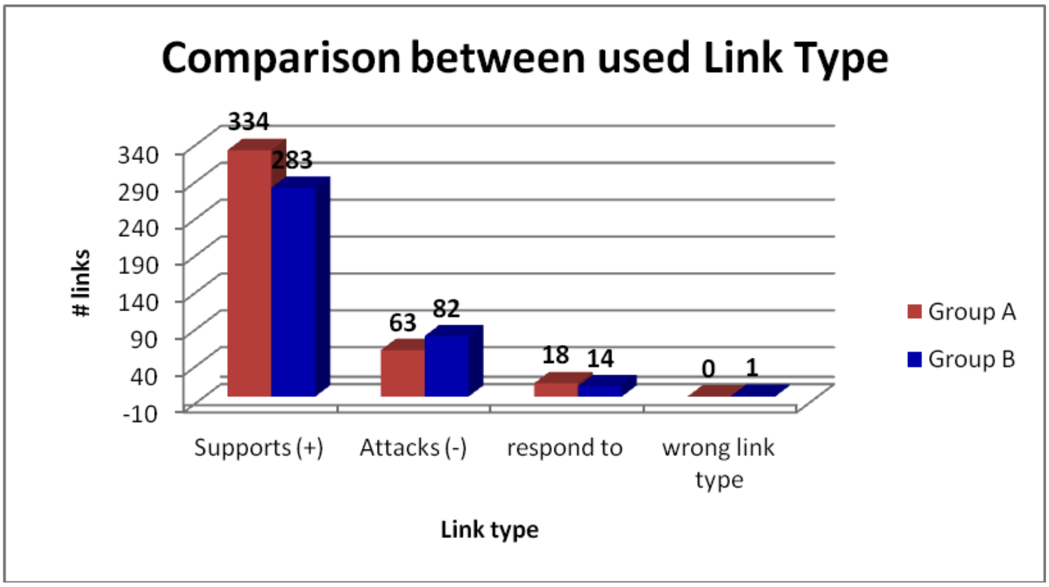


Figure 26. Comparison between Group A's and Group B's used links type

In order to test the hypothesis that users in the treatment group have been more active in the discussion than users in the control group, we performed a one-tail Independent Sample T-tests using SPSS (Statistical Package for the Social Sciences) to assess if visual feedback impact on users' activity. In particular, the hypotheses to test are:

$$H_0: \text{Users' activity}_a = \text{Users' activity}_b$$

$$H_1: \text{Users' activity}_a > \text{Users' activity}_b$$

In this case we used a one-tail T test because we want to test the hypothesis that Users' activity of group A is greater than users' activity level of group B. As in SPSS there is no option to specify a one-tailed test, we need to look in a table of critical t values to determine the critical t and to compare it with the observed t value. The critical t with 62 degrees of freedom, $\alpha = 0.05$ and one-tailed is 1.671. The decision rule to determine if we can reject the null hypothesis or not is: if the one-tailed critical t value is less than the observed t value and the means are in the right order ($\bar{x}_a > \bar{x}_b$), then we can reject H_0.

In our case, the critical t value is 1.671 and the observed t value is 1.820; therefore, as $T_{critical} < T_{observed}$ and as $\bar{x}_a > \bar{x}_b$ (respectively 27,4 and 18,38), H_0 is rejected and H_1 is accepted. Put differently, it is possible to claim that users' activity level of group A is significant higher than users' activity level of group B. Thus, we can conclude the group A that used the Debate Dashboard had better performance than the group B that used the plain version. As initially the two groups were not significantly different, it is possible to conclude that the better performance depends on the provision of individualized feedback.

In order to measure the magnitude and direction of the difference between treatment group and control group, we performed an Effect size (ES) test based on means (Cohen's *d*) (Cohen, 1988). In other words, ESs provide this information by assessing how much difference there is between groups. By computing ESs we can analyze the strength of the findings of an empirical research.

In general, Cohen's *d* is defined as the difference between two means divided by a standard deviation pooled for the data:

$$d = \frac{\bar{x}_a - \bar{x}_b}{S_{pooled}}$$

The formula to calculate S_{pooled} is:

$$\sqrt{\frac{[s_A^2 * (n_A - 1) + s_B^2 * (n_B - 1)}{n_A - n_B - 2}}$$

In this case, Cohen' *d* ES is equal to 0.47, therefore, we can affirm that there is an ES. This means that the intervention effect, that is the use of visual feedback, not only had an effect on users' performances, but, in line with Cohen [1988] it can be considered a *medium* effect. In other words, by calculating Cohen's *d*, we evaluated the statistical significance of effect.

Further analysis should be performed in order to better measure the impact of visual feedback on common ground building and the effect of mutual understanding on users' performances.

6.4 Post-session questionnaire data analysis

A further instrument used in the experiment to collect data was a follow-up questionnaire for both groups. It is composed of 28 items (7-point Likert scale) to measure four latent constructs of theoretical model, namely Mutual Understanding, Quality of online Collaboration, Quality of Decision and Usability.

Before proceeding with analysis of post-session questionnaire database, we assessed the reliability and validity of the measurement instrument. The latter, indeed, to be effective, must be reliable and valid to not lead to the invalidation or inaccuracy of surveyed data. In simple terms, reliability means that an instrument will consistently measure something; validity means that it will measure what it is intended to measure [Spector, 1992]. Measurement reliability refers to the proportion of variance attributable to the true score of the latent variable [DeVellis, 1991]. The measurement reliabilities of the constructs were evaluated using Cronbach's α and Average Variance Extracted (AVE).

In literature, Cronbach's α is one of the most common index used to evaluate internal consistency. Cronbach's α is a measure of the proportion of variance among a group of indicators that is attributable to a common factor [Cronbach, 1951]. Cronbach's α provides an index score that ranges from 0 to 1. The α for a good scale should be greater than 0.7, meaning that 70 percent of the variance among the indicators is common. In Table 11, we show the Questionnaire items, the removed items, the latent constructs which we want to measure and alpha values. In particular, by analyzing inter-item total correlation matrix, we found some items that had a low inter-correlation rate that impact negatively on Cronbach's alpha values. Indeed, by deleting those items, the alpha values of the latent constructs increase.

In particular, as showed in Table 11, the deleted items are: Q4, Q14, Q21, and Q22. By deleting Q4 (Quality of Online Collaboration cluster), the Cronbach's alpha varied from 0.67 to 0.763. While by deleting Q14, Q21, Q22 in Mutual Understanding cluster, the alpha values changes from 0.55 to 0.75. In addition, in the case of Quality of Decision, we considered Cronbach's Alpha standardized items because individual scale items are not the same. Indeed, items Q11 and Q12 ask users to indicate their personal decision before and after group discussion; while Q13 asks users to indicate what group decision is.

Therefore, the α for each of the scales used in this study exceeds 0.7. This confirms the strength of the instrument used in measuring the latent constructs. In particular, the investigated items results to be perfectly correlated to the construct to which they refer.

Table 11. Questionnaire items, Removed Items, Latent Construct and alpha values

#	Questionnaire items	Removed Items	Latent Construct	Cronbach's α
Q1	The interaction level developed during Cohere-mediated conversation was satisfying		Quality of online Collaboration	0.763
Q2	I found the online discussion interesting and engaging			
Q3	Collaboration was effective to solve assigned problem			
Q4	I found it difficult to keep track of the conversation	*Low inter-correlation rate*		
Q5	The argument map was helpful in facilitating knowledge sharing among team members			
Q6	I shared my own knowledge about the task with my teammates			
Q7	I found that my teammates have shared own their knowledge about the task			
Q8	The group developed a good amount of work			
Q9	The group made a good job			
Q10	I think that, at the end of online debate, the group has a common position about the discussion topic		Quality of Decision	0.744
Q11	What is your initial decision before discussing with other group members?			
Q12	What is your decision at the end of online debate?			
Q13	What is group' s decision at the end of the discussion?			
Q14	In general, I have not had problems to understand the meaning of other team members' posts	*Low inter-correlation rate*	Mutual Understanding	0.752
Q15	In general, I think that the other team members have understood my contributions without difficulty			
Q16	I could easily understand (tell) what my teammates had done on Cohere			
Q17	I could easily understand who has done what			
Q18	I could easily say who is online on Cohere			

#	Questionnaire items	Removed Items	Latent Construct	Cronbach's α
Q19	My teammates and I developed better understanding about each other over the two weeks		Mutual Understanding (as above)	0.752 (as above)
Q20	My teammates and I developed shared understanding about the task over the time			
Q21	I found online conversation is often redundant	*Low inter-correlation rate*		
Q22	I found there are many irrelevant posts respect the assigned task	*Low inter-correlation rate*		
Q23	Interaction with the system does not require a lot of my mental effort		Usability	0.845
Q24	I find the system to be easy to use			
Q25	I enjoyed collaborating with my teammates using Cohere			
Q26	I would enjoy working with my teammates again using Cohere			
Q27	It was easy to communicate effectively given the tools available			
Q28	Cohere supports and facilitates collaboration among online users			

A second measurement used to evaluate the reliability of questionnaire was the Average Variance Extracted (AVE). It measures the amount of variance captured by the indicators in relation to the amount of variance due to measurement error [Fornell and Larcker, 1981]. AVE should be greater than 0.5 [Chin, 1998]. With respect to the data collected for this study, all AVE scores for the measures used exceeded the 0.5 threshold (Table 12).

Table 12. Average Variance Extracted values

Constructs	**AVE**
Mutual Understanding	0,909
Quality of Collaboration	0,807
Quality of Decision	0,832
Usability	0,883

The Cronbach's α and Average Variance Extracted values exceeded the recommended thresholds. Therefore, the measurements used for this study exhibited adequate internal consistency reliability.

In order to evaluate the validity of measurement instrument, we computed Square-Root of AVE. Validity refers to the extent to which the interpretation derived from a measurement procedure or the inferences made on the basis of measurement are correct. In particular, discriminant validity is the extent to which measures of different concepts are distinct [Bryant, 2000]. Discriminant validity was assessed using the method prescribed by Gefen and Straub [2005]. The procedure to assess discriminant validity is the AVE analysis. The AVE analysis is performed by comparing the square root of the AVE with the correlation between the construct and every other construct. The square root of the AVE has to be larger than the correlations with the other constructs [Fornell and Larcker, 1981]. Unfortunately, there are no definitive guidelines to indicate how much larger the square root of the AVE has to be. In each case, the square root of the average variance extracted is much larger than the correlations of the construct with the all of the other constructs. Therefore, the data passed the test of discriminant validity as well. This means that the indicators (items) used to measure the latent constructs have much more in common with the construct that they should measure rather than with the other latent variables in the questionnaire.

Table 13. Discriminant validity

CONSTRUCT	AVE	SIC
Mutual Understanding	0,909	0,564; 0,234; 0,805
Quality of Collaboration	0,807	0,564; 0,234; 0,624
Quality of Decision	0,832	0,234; 0,234; 0,199
Usability	0,883	0,624; 0,805; 0,199

Therefore, both reliability and validity analysis of measurement instrument confirm and validate its goodness (Table 13). Here are also the descriptive statistics relating to the collected data through post-session questionnaire used for both the group A to group B.

Table 14 shows the median, mode, range and inter-quartile range for all the collected data dividing data indicating performance among the constructs and analyzed by comparing the 2 groups of the experiment, so to facilitate comparison between the treatment group and control groups. Before proceeding with data analysis, it is important to highlight that response rate of Group A was 100%, that is all participants to the experiment completed the post-session questionnaire, while in the group B only 36 out of 39 students filled in it (i.e. response rate 92 percent).

Table 14. Descriptive Statistics Group A and Group B

Construct	Items	Median		Mode		Q1		Q3		Range		IQR	
		A	B	A	B	A	B	A	B	A	B	A	B
Quality of Collaboration	Q1	5	5	5	5	4,75	4	5	6	4	4	0,25	2
	Q2	6	5	6	5	5	5	6	6	4	4	1	1
	Q3	5	5	6	5	5	3	6	6	4	3	1	3
	Q5	5	6	5	6	5	5	6	6	4	4	1	1
	Q6	6	5	6	5	5	5	6	6	3	4	1	1
	Q7	6	5	6	5	5	4	6	6	5	5	1	2
	Q8	6	6	7	6	5	5	7	6,25	3	5	2	1,25
	Q9	5	5	5	5	5	4	6	6	4	6	1	2
Quality of Outcome	Q10	6	5	6	5	5	5	6	6	5	4	1	1
Quality of Decision	Q15	5	5,5	6	6	5	4	6	6	2	5	1	2
	Q16	5	5	5	5	4,75	4	6	5,25	4	5	1,25	1,25
	Q17	5	5	5	5	3,75	4	6	5	4	5	2,25	1
	Q18	5	4	5	5	4	3	5	6	6	6	1	3
	Q19	5	5	5	5	4,75	4	6	6	5	5	1,25	2
	Q20	6	6	6	6	5	5	6	6	3	4	1	1
Cohere usability	Q27	6	5,5	6	6	5	4	6	6	4	4	1	2
	Q28	5	6	5	5	5	5	6	6	5	4	1	1
	Q29	6	5	6	6	5	5	6	6	4	6	1	1
	Q30	5	4,5	6	4	5	4	6	6	5	6	1	2
	Q31	5	5	5	3	4	3	5	6	3	6	1	3
	Q32	5	5	5	6	5	4	6	6	5	5	1	2

In order to evaluate the impact of visual, social and conversational feedback on users' mutual understand and on users' performances, we performed T-test to verify whether the two groups are significantly different. Before proceeding with the computation of T-tests, we ensured the normality of sample distribution. Indeed, a basic assumption is that each of the two database collected through post-session questionnaire follows a normal distribution. In this study, we tested normality by using the Shapiro-Wilk normality test. We used Shapiro-Wilk test as it is more appropriate for small samples (x<50). We computed this test for each of our measured constructs for both group, namely Mutual Understanding, Quality of online Collaboration, Quality of Decision and Cohere Usability. In Table 15, we show the results of Shapiro-Wilk normality test.

Table 15. Normality test

Construct	**Group**	**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**
Mutual Understanding	A	.964	25	.500
	B	.964	36	.278
Quality of Collaboration	A	.955	25	.323
	B	.971	36	.448
Cohere Usability	A	.960	25	.414
	B	.984	36	.875

The results confirmed that our samples are normally distributed as all Sig. value> 0.05. This lets us to accept the null hypothesis (H_0), confirming that the data comes from samples normally distributed.

In order to determine normality graphically Figures 27, 28 and 29 show the Q-Q Plot (output of SPSS). If the data are normally distributed then the data points will be close to the diagonal line. If the data points stray from the line in an obvious non-linear fashion then the data are not normally distributed. As it is possible to note from the normal Q-Q plot below, in our case, the data is always normally distributed.

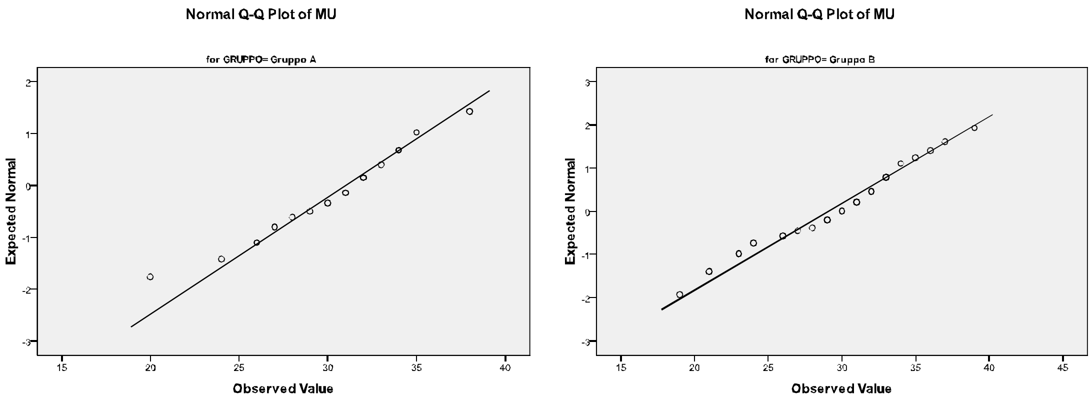


Figure 27. Data distribution of Mutual understanding construct for Group A and Group B

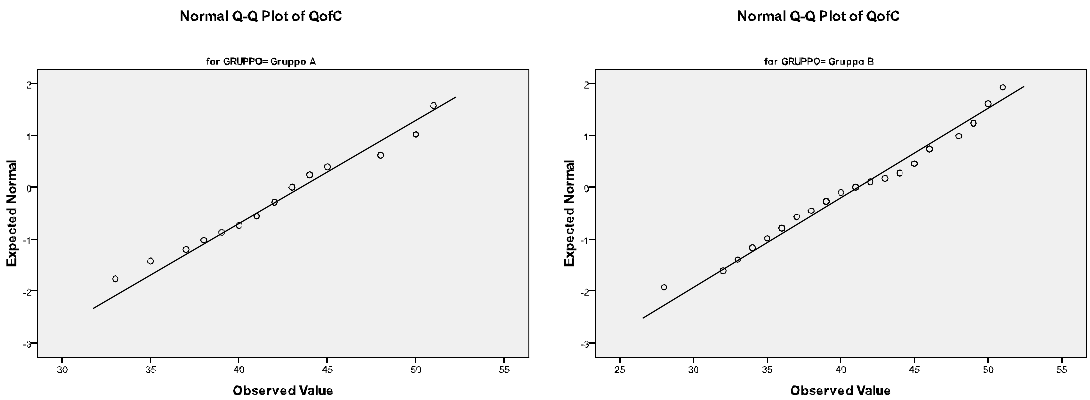


Figure 28. Data distribution of Quality of Collaboration construct for Group A and Group B

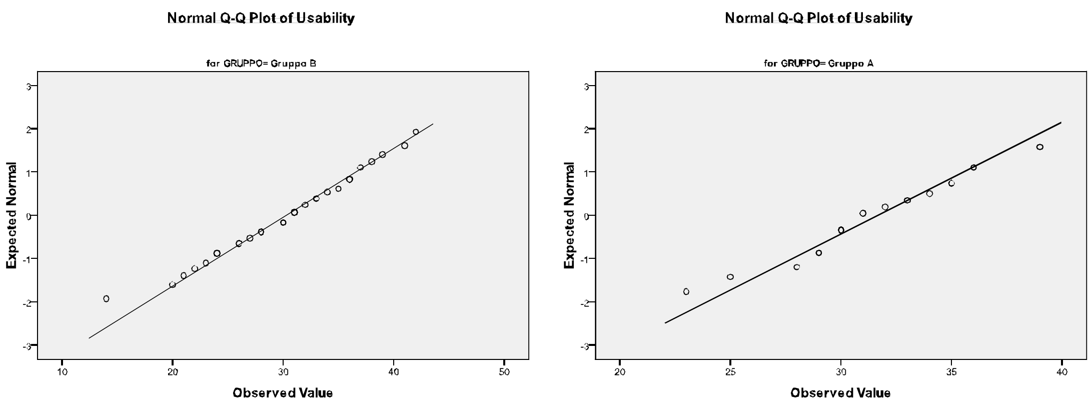


Figure 29. Data distribution of Cohere Usability construct for Group A and Group B

Ensured the normality of the data with the above tests, it was possible to perform the t-verify if social and conversational feedback provided by the Dashboard Debate have improved mutual understanding and users' performances. We performed one-tail T test, because we hypothesized that users' performances and mutual understanding of group A are better than ones of group B. In particular, the set of hypotheses are:

Mutual Understanding: H_0: $MU_a = MU_b$;
H_1: $MU_a > MU_b$;

Quality of Collaboration: H_0: $QofC_a = QofC_b$;
H_1: $QofC_a > QofC_b$;

Cohere Usability: H_0: $Usab_a = Usab_b$;
H_1: $Usab_a > Usab_b$;

Regarding the first 2 hypotheses about QofC and MU, it was possible to reject H_0 at 95%, given that t critical value is 1,671 (df = 59; α =. 05) is less than t values observed for the 2 constructs (Table 16). While, for Usability, we have to accept H_0 for α =. 05 as t critical value is greater than t observed. In reality, we expected that usability of the "Augmented" Cohere version could reduce because of the presence of more widgets and different features than "Plain" version. In other words, "augmented" version could be resulted more complicated to used and therefore ask users a higher effort.

Table 16. Results One-Tail T test

	$T_{observed}$	t tab α= .05 (df=59)	t tab α= .01 (df=59)	t > t tab (α= .05)	t > t tab (α= .1)
Mutual Understanding	1,965	1,671	1.296	reject H_0	reject H_0
Quality of Collaboration	1,908	1,671	1.296	reject H_0	reject H_0
Quality of Decision	1.509	1,671	1.296	accept H_0	reject H_0
Cohere Usability	1,075	1,671	1.296	accept H_0	accept H_0

As showed in Table 16, the results support the most part of our hypotheses. Thus, we can state that visual feedback impact positively on mutual understanding and users' performances. In other words, it is possible to affirm that social and conversational feedback increases and supports mutual understanding (α =.05) among members of group A and improve the quality of collaboration (α =.05) and quality of decision (α =.1). In particular, by having analyzed the two groups before experiment phase on the basis of academic proficiency indicator, and not having found no significant differences, we can affirm that the better results do not depends on inherent users' abilities, but they may be attributed to the provided feedback. In nutshell, mutual understanding, quality of collaboration and quality of decision of group A is significantly different from mutual understanding and users' performances of group B.

As already mentioned in the previous Chapter, Quality of Decision is measured by evaluating users' decision accuracy. Also in this case (Figure 30), group A has been able to forecast the right trend of gold price, while group B was not able to forecast the correct one. In particular, both groups forecast that oil and gold price increased; in reality, gold price increased from \$ 1535,30 (05.30.2011) to \$ 1840,00 (08.30.2011), instead oil price varied from \$ 100.33 (05.30.2011) to \$ 88.80 (08.30.2011).

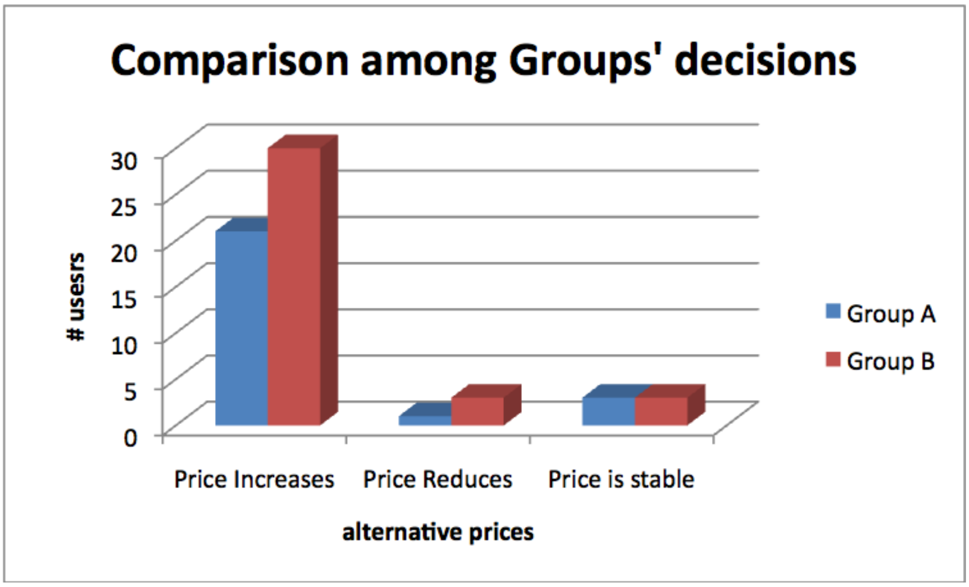


Figure 30. Comparison among users' decision for Groups

In order to measure the magnitude and direction of the difference between treatment group and control group, we performed an Effect size (ES) tests based on means (Cohen's *d*) [Cohen, 1988] for each T-test.

In this cases (Table 17) we can affirm that the ESs are *medium*. This means that the intervention effect, that is the use of visual feedback, had an effect on users' performances and mutual understanding. Only in the case of Usability performance, the ES is considered *small.*

Table 17. Effect size tests

Effect size	
Mutual Understanding	0,51
Quality of Collaboration	0,50
Quality of Decision	0,40
Usability	0,26

In conclusion, it is possible to state the users' performances of group A was better than ones of group B because of the provision of social and conversational feedback. In accordance with Cohen [1998], these differences are statistically significant as well.

In the next paragraphs we performed further analysis to better understand the role and the impact of each visual feedback on users' mutual understanding and users' performances; in addition, we run some tests to analyze whether and the role of improvement of mutual understanding on users' understanding.

6.5 Virtual Machine Database

In order to track and record the utilization of visual feedback, students of group A installed on their computers a Virtual Machine and they used it to work and browse in Cohere. By using the Virtual Machines it is possible to know what URLs users have used. As each visual feedback has an own URL, as consequence, we can know what feedback and count how many times students use it (frequency).

Before proceeding to the data analysis of Virtual Machine database, we cleaned up it. Indeed, first, we deleted all those URLs that do not regard Cohere use. For instance, students used virtual machine also to look for information about their collaborative task i.e. http://www.gold.org, http://www.borsainside.com, http://www.economist.com, http://www.ilsole24ore.com. Second, we removed all URLs relating to users' login and logout, as well as home page and own user' personal page. Third, we eliminated all URLs pertaining to users' producing activity. In other words, we removed URLs regarding the creation of posts and connections. The basic idea is to focus exclusively on users' browsing activity in Cohere, because we think that this activity is crucial for users to gather further information about other group members' activity and online discussion. In other words, we did not delete all those URLs relating to the visualization of nodes list, connections list and discussion group page. Indeed, by browsing in these pages, users can visualize information about discussion content development and users' paticipation. In addition, we supposed that this information could support the creation of mutual understanding about users and discussion content.

Once cleaned up the database, we proceeded to evaluate the frequency of the use of each visual feedback (Figure 31) in all the group. In other words, we counted how many times each feedback was used by group A and calculated the percentage of utilization for each of it, also respect to the other users' browsing activity.

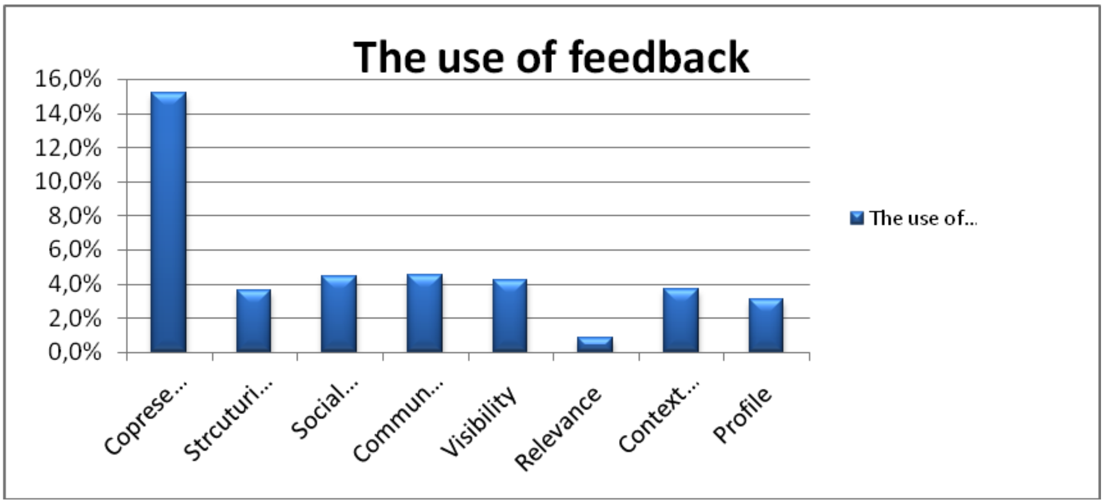


Figure 31. Frequency of use for each feedback

As it is possible to note, the most used feedback is *Copresence,* while the least used is *Relevance* feedback. This shows that for users is very important to know with they are speaking. In general, absorption feedback are the least used feedback. Maybe, this could depend on the inherent features of Cohere, that already supports users in the sense-making of discussion, notwithstanding the development of the map. Other often-used feedback are: *Community's history* (4,5%), *Social Structure* (4,4%) and *Visibility* (4,2%). The first two feedback belongs to the *Community Feedback* category, while the last belongs to the *Interaction Feedback* class. This means that users need of social and conversational information which are lacking or hidden and, therefore, more difficultly deducible.

In conclusion, not only visual feedback have a significant impact on mutual understanding and users' performances, but some feedback is considered also very used by students. Further more in-depth analysis should be performed on the use of diverse feedback to evaluate different its aspects, such as its design, its efficiency and eventually possibilities of improvement.

In the following paragraphs, we show the results of SEM analysis in order to understand the role of each sub-classes of feedback on mutual understanding and users' performances. Moreover, we evaluate the mediation role of mutual understanding among the different classes of feedback and users' performances. This depends on the idea that increasing of mutual understanding should result in improvement of users' performances.

6.6 Structural Equation Modelling Analysis

Recall that the overarching goal of this dissertation is to investigate the impact of visual feedback on mutual understanding and on users' performance. A theoretical model was proposed based on a set of statements of correlations between variables. In the sections that follow the theoretical model is tested using the collected data. The data analysis proceeds in two steps. First, the measurement model was assessed for validity and reliability. Then the structural model was assessed. In this phase we used SmartPLS to undertake the examination. As already mentioned, SmartPLS is a software application that enables the user to perform path modelling with latent variables using the partial least squares method.

In particular, in the following paragraphs, first we evaluate measurement model and then the validity of the structural model and the hypotheses that the structural model was designed to evaluate.

6.6.1 Measurement Model

As mentioned in the previous Chapter, the measurement model (or outliner model) shows how constructs have been operationalized and, thus, measured by using manifest variables. The analysis of the measurement model was undertaken to assess the reliability and validity of it. Indeed, to be effective, measurements should be reliable and valid. In simple terms, reliability means that an instrument will consistently measure something; validity means that it will measure what it is intended to measure [Spector, 1992]. In the following we describe the procedures that were undertaken to assess the reliability and validity of the measurements used in this study.

We have to make a precision about the evaluation of measurement model. In this case, we are measuring the reliability and the validity of all our theoretical model. Thus, these analysis are quite different from ones performed for post-session questionnaire. In other words, we consider all the correlation relationship among all the variables of the model.

The measurement reliabilities of the constructs were evaluated using Cronbach's α, composite reliability, and average variance extracted (AVE). Cronbach's α is a measure of the proportion of variance among a group of indicators that is attributable to a common factor [Cronbach, 1951]. The results are shown in Table 18.

Table 18. Cronbach's alphas, Composite Reliability, AVE e sqrt-AVE

Reliability Measure	**MU**	**QofD**	**Usability**
α	0,788	0,675	0,711
Composite Reliability	0,853	0,793	0,813
AVE	0,507	0,547	0,51
Sqrt-AVE	0,712	0,74	0,714

Before proceeding to the analysis of each reliability measurements used in this study, we have to make a precision about Quality of Collaboration construct. In our model we defined the items that measure Quality of Collaboration construct as formative and not as reflective. In nutshell, reflective variables are caused by the construct and reflect its variation; while formative variables cause the latent construct. We decided to treat these items as formative rather than reflective variables for two reasons, because: i. they are cause of construct and not viceversa, and ii. this change have improved the quality of the model. Indeed, according to literature, the use of formative variables, in some cases, such as business and management studies, could improve the model and, thus, to be better than reflective variables [Diamantopoulous and Siguaw, 2006; Podsakof et al, 2006]. As such items are considered formative, SmartPLS do not compute the reliability measures shown in Table 18.

Let's to analyze each of computed measurements. As already mentioned, Cronbach's α values should range from 0 to 1. The Cronbach's alpha should be greater than 0.7 to have a good scale. In our case, all the alpha values exceed this threshold, except that in Quality of Decision construct. This could be due to the fact that we used only two items to measure this construct (Q10 and Q12) and because one of them is a dichotomic variable. The other two variables were deleted after performing a first run of SEM analysis and as their path coefficients were negative, we decided to exclude them from the analysis.

Composite reliability is similar to Cronbach's α. It is designed to assess the same form of reliability: internal consistency reliability. Like Cronbach's α Composite reliability provides an index score. The difference is that Cronbach's α assumes that all of the indicators have the same reliability, while composite reliability does not. Consequently, the results for the two indexes are different and the standards for evaluating them are a little different. For exploratory research, composite reliabilities should be greater than 0.6. With respect to this study, all values were greater than 0.7, which provides further evidence that the measurement instruments used in this study are reliable.

According to Chin [1998], AVE should be greater than 0.5. With respect to our model and, thus, latent variables, all AVE scores for the measures used exceeded the 0.5 threshold.

In conclusion, the Cronbach's α, composite reliability, and average variance extracted values exceeded the recommended thresholds. Therefore, the measurements used for this study exhibited adequate internal consistency reliability.

With regard to validity of measurement model, in SEM two forms of validity are usually assessed: convergent validity and discriminant validity. Convergent validity is the degree to which multiple measures of the same construct demonstrate agreement or convergence [Bryant, 2000]. Convergent validity is attained when multiple measures of an item represent the same underlying construct. Such measures should be strongly and significantly correlated. Convergent validity was assessed by the using the AVE value presented in Table 18. In order to exhibit adequate convergent validity, the AVE of a construct must be greater than 0.5. In other words, the construct must account for more than half of the variance of its indicators. For this research, the AVE was greater than 0.5. Consequently, the data was deemed to exhibit adequate convergent validity.

Discriminant validity is the extent to which measures of different concepts are distinct [Bryant, 2000]. Discriminant validity was assessed using the method prescribed by Gefen and Straub [2005], that is the AVE analysis. The AVE analysis is performed by comparing the square root of the AVE with the correlation between the construct and every other construct. The square root of the AVE should be much larger than the correlations with the other constructs [Fornell and Larcker, 1981]. In Table 19 we show correlations between constructs and the square root of the AVE.

Table 19. Discriminant validity

Constructs	SRAVE	SIC
Mutual Understanding	0,712	0,425 ; 0,666
Quality of Decision	0,739	0,425 ; 0,356
Usability	0,714	0,666 ; 0,356

In each case, the square root of the average variance extracted is much larger than the correlations of the construct with the all of the other constructs. Therefore, the data passed the test of discriminant validity.

Once evaluated and ensured the reliability and validity of measurement model, we can proceed to the evaluation of the structural model and, thus, to test our hypotheses.

6.6.2 Structural Model

In this paragraph, we assess the structural model and test the validity of our hypotheses. The assessment of the structural model consists of an examination of the R^2 and estimation of path coefficients [Henseler *et al*., 2009].

The structural equations in PLS are calculated using OLS multiple regression. Consequently, they are interpreted in the same manner as the standardized beta coefficients of ordinary least squares. The beta coefficients for each path are presented in Table 20. The significance of the path coefficients was assessed using the bootstrapping technique. Bootstrapping is a computer-based method for assessing the accuracy of statistical estimates [Efron and Tribshirani, 1998]. Bootstrapping repetitively re-samples with replacement in order to create an estimate of the distribution of a statistic [Mooney and Duval, 1993]. PLS uses bootstrapping to create a bootstrapping distribution for each path coefficient. The mean and a standard error can be calculated from the bootstrapping distribution. The mean and standard error allow a *t*-value to be calculated [Henseler et al., 2009] which can be used to estimate the significance of the path coefficients [Chin, 1998].

To run the bootstrapping procedure in PLS we have to set the number of re-samples This number should be greater than 100, but greater than 200 is preferable. Since larger numbers of re-samples lead to more reasonable estimates of standard error [Tenenhaus et al., 2005], the bootstrapping procedure was undertaken with 250 samples. The results of the model are presented in Figure 32.

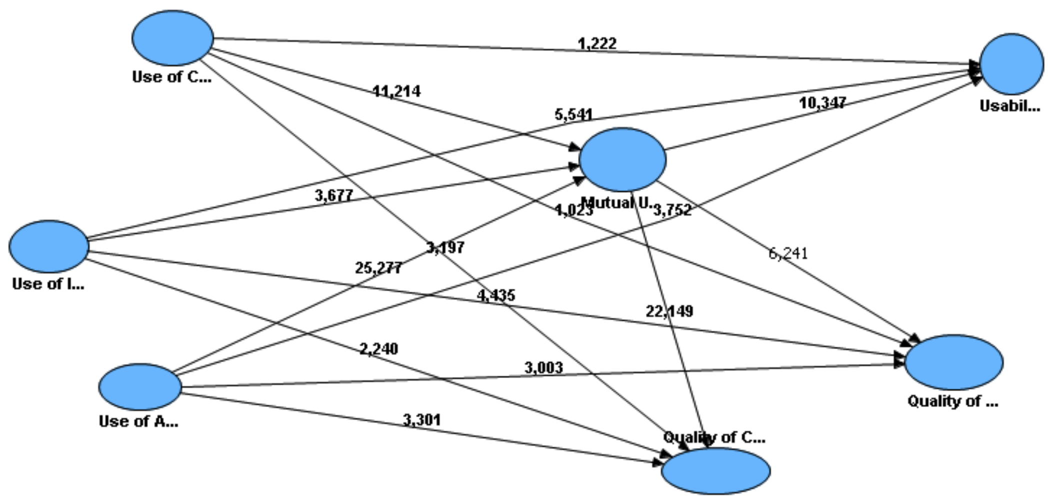


Figure 32. Structural model results – Bootstrapping technique

The *t*-statistics and *beta* coefficients are presented in Table 20. From the analysis of results, thirteen hypotheses of defined model are supported and just two are rejected. It is important to highlight that a coefficient is significant if t-statistic is higher than 1,96.

Table 20. Bootstrapping results

Hypotheses	Path	Beta	*t*-statistic	Validation
H1	CF → MU	0,568	8,236	Supported
H2	IF → MU	-0,137	3,36	Supported
H3	AF → MU	-0,511	21,591	Supported
H4	MU → QofC	0,979	20,257	Supported
H5	MU → QofD	0,293	6,119	Supported
H6	MU → Usab	0,519	9,996	Supported
H7	CF → QofC	-0,517	2,663	Supported
H8	CF → QofD	-0,096	0,873	Not supported
H9	CF → Usab	-0,114	1,078	Not supported
H10	IF → QofC	0,325	2,012	Supported
H11	IF → QofD	0,344	3,824	Supported
H12	IF → Usab	0,286	4,762	Supported
H13	AF → QofC	0,267	3,435	Supported
H14	AF → QofD	-0,258	2,806	Supported
H15	AF → Usab	-0,346	3,386	Supported

These hypotheses are exploratory in nature. No previous studies have provided quantitative evidence on the influence of visual feedback on mutual understanding and on users' performances. Rather these hypotheses were based on qualitative studies. For this reason, this research could be intended to verify and quantify the results of the qualitative studies.

As showed in Table 20, hypothesis 1, hypothesis 2 and hypothesis 3 were supported. This set of hypothesis was intended to evaluated the impact of visual feedback on

Mutual Understand. It is possible to state that all three feedback affect significantly mutual understand given that their t-statistics are always higher than 1,96. In order to analyze the type of relationship among the independent variable (in this case the classes of feedback and) the dependent variable (that is, the mutual understanding), we have to consider also the *beta* value. In particular, the results show that amount of Interaction and Absorption feedback were negatively related with Mutual Understanding (respectively β = -0,137 and β = -0,511). These results are contrary to expectations and are contrary to the results reported in previous researches. Indeed, both feedback is supposed to foster common ground building both on process (Interaction feedback) and on content (Absorption feedback). These findings are not aligned with previous qualitative and quantitative researches by Clark and Brennan [1991] and Convertino and his collaborators [2004; 2008; 2009], which reported that the presence of interaction feedback facilitates mutual understanding construction. These results could depend on the fact that we were not able to provide all feedback individualized by Clark and Brennan due to the inherent features of Cohere.

With regard to the second set of hypotheses, the hypothesis 4, hypothesis 5 and hypothesis 6 were supported by SmartPLS findings. In particular, mutual understanding significantly and strongly impact on users' performances, namely Quality of Collaboration (*t-statistic* = 20,257; β = 0.979), Quality of Decision (*t-statistic* = 6.119; β = 0.293) and Usability (*t-statistic* = 9,996; β = 0.519). These findings confirm both as expected and as emerged from literature about the positive effect of common ground on group coordination, collaboration and effectiveness as well [Convertino *et al.,* 2004; 2008; 2009].

As already mentioned, we aim at measuring also the effect of social and conversational feedback on the three level of users' performances. We analyzed these results by each class of feedback. In particular, Community feedback does not impact significantly on Quality of Decision and on Usability. With regard the impact of visual feedback on quality of decision is in line with as emerged from literature. Indeed, several studies show that anonymous improves quality of decision as individuals are not affected by social aspects, such as reputation and social acceptance. Additionally, regarding

Community feedback, it is plausible that it reduces the Cohere usability given that users have more features that that can be used. Instead, Community feedback impacts significantly on Quality of Collaboration, but negatively (β = - 0.517).

With regard to the impact of Interaction feedback on users' performance, the results show a significant and positive relationships among variables. In other words, hypothesis 10, hypothesis 11 and hypothesis 12 are supported (respectively, β = 0.325; β = 0.344; β = 0.286). This means that visual feedback about interaction process, in particular co-presence and visibility feedback, impact on Quality of Collaboration and Decision and on Usability. These results confirm as emerged in literature. Indeed, several researches have proved that the provision of conversational feedback and hidden information impact positively on quality of discussion, its outcome and interaction processes among users [Shneiderman, 2000; Erickson *et al.*, 2002; Edelson *et al,* 1996; Ryall *et al.,* 2004].

Finally, hypothesis 13, hypothesis 14 and hypothesis 15 are supported. In particular, it is emerged that Absorption feedback impact significantly and positively on quality of collaboration (*t-statistic* = 3,435; β = 0.267). This result confirms as we originally supposed. Indeed, by providing this feedback, we aim at supporting online users to make sense of discussion and to pitch into it in the right way. The other two results are contrary to what we supposed. Indeed, findings show that absorption feedback impact significantly, but negatively on quality of decision and Cohere usability (respectively, *t-statistic* = 2,806; β = -0.258 and *t-statistic* = 3,386; β = -0.346). With regard to Usability performance, we think that the problem is the design and the features of visualization tools that make harder the use of the platform. Respect to the quality of decision, we expected that, by providing compact information about generated content, the quality of outcome may improve.

6.6.3 Mediation Results

Recall that three mediation effects were hypothesized (H16 – H24). Mediation occurs when the cause-effect relationship between a predictor variable and a criterion variable occurs through an intervening variable. When the intervening variable accounts for all of the influence of the predictor variable on the criterion variable the relationship is said to be fully mediated. When the direct path of influence from the predictor variable to the criterion variable is reduced but not brought to zero when the intervening variable is introduced into the model the relationship is said to be partially mediated. Mediation relationships are of interest because they go beyond simply describing correlations to explain how processes work [Preacher and Hayes, 2008]. The hypothesized mediation effects were tested using PLS technique.

In order to perform the mediation analysis, a was created that depicted a relationship between the independent variable (visual feedback) and the dependent variable (users' performances) (Table 21).

Then a second model was created, namely the mediated model that includes the mediator variable (Mutual Understanding) (Table 22). The screenshots of two models deriving from SmartPLS elaborations are presented in the Appendix C.

The two models were tested by using PLS. The path betas and R^2 were recorded. The *t*-values were used to assess the significance of the relationships.

These hypotheses aim at assessing the role of Mutual Understanding as mediator. In other words, Mutual Understanding was hypothesized to mediate the relationships among visual feedback and users' performances. It was expected that the influence of visual feedback on users' performances was through its influence on Mutual Understanding.

Table 21. Results of Simple Model

Simple Model Path	Indipendent → Dependent		
	Beta	t-values	R^2
COMMUNITY → USABILITY	0,351	2,833	0,544
INTERACTION → USABILITY	0,251	2,516	
ABSORPTION → USABILITY	-0,748	7,407	
COMMUNITY → QofC	0,44	1,614	0,602
INTERACTION → QofC	0,725	5,186	
ABSORPTION → QofC	-0,506	3,176	
COMMUNITY → QofD	0,085	0,46	0,312
INTERACTION → QofD	0,385	3,792	
ABSORPTION → QofD	-0,474	5,746	

Table 22. Results of Mediated Model

Mediated Model Path	Independent→ Dependent		Independent→ Mediator		Mediator → Dependent		
	beta	t-values	beta	t-values	beta	t-values	R^2
COMMUNITY → MU → USAB	-0,114	1,078	0,568	8,236	0,519	9,996	0,605
INTERACTION → MU → USAB	0,286	4,762	-0,137	3,36	-	-	
ABSORPTION → MU → USAB	-0,346	3,386	-0,511	21,591	-	-	
COMMUNITY → MU → QofC	-0,517	2,663	-	-	0,979	20,257	0,71
INTERACTION → MU → QofC	0,325	2,012	-	-	-	-	
ABSORPTION → MU → QofC	0,267	3,435	-	-	-	-	
COMMUNITY → MU → QofD	-0,096	0,873	-	-	0,293	6,119	0,318
INTERACTION → MU → QofD	0,344	3,824	-	-	-	-	
ABSORPTION → MU → QofD	-0,258	2,806	-	-	-	-	

As showed in Table 23, the hypothesis 21, hypothesis 22, hypothesis 23 and hypothesis 24 were not supported. In particular, the results demonstrate that the R^2 of the mediated model was higher than the simple model. Indeed, when Mutual Understanding was added to the model as a mediator, the R^2 for the model increased, respectively to 0.605, 0.71 and 0.318. In other words, the mediated model explains more of the variance in users' performance than the simple model. Actually, this means that the mutual understanding explains a part of variance of users' performances. Additionally, when the independent variables and mediator variable were regressed on the dependent variable (users' performances), also the beta for the paths among the independent variables (classes of visual feedback) and the dependent variables (users' performances) reduced. This indicates that a portion of the impact of visual feedback on users' performances is through Mutual Understanding. With regard to the hypothesis 21, hypothesis 22, hypothesis 23 and hypothesis 24, the beta paths did not reduce, but increase. In particular, this means that mutual understanding does not mediate the relationship and no portion of the influence of absorption feedback on users' performances is through mutual understanding. The same happens with regard to interaction feedback on usability performances.

Table 23. Mediation results

Hypotheses	**Path**	**Comparison (β1 - β2)**	**Validation**
H16	COMMUNITY → MU → QofC	0,957	Supported
H17	COMMUNITY → MU → QofD	0,181	Supported
H18	COMMUNITY → MU → Usab	0,465	Supported
H19	INTERACTION → MU → QofC	0,4	Supported
H20	INTERACTION → MU → QofD	0,041	Supported
H21	INTERACTION → MU → Usab	-0,035	Not supported
H22	ABSORPTION → MU → QofC	-0,773	Not supported
H23	ABSORPTION → MU → QofD	-0,216	Not supported
H24	ABSORPTION → MU → USAB	-0,402	Not supported

6.7 Discussion

This research uses a common ground and grounding approach in order to assess argumentation's mediation capability in supporting online distributed deliberation and decision making process. According to the grounding theory, argumentation tools are not so able to foster easier, smoother and free communication and interaction. Indeed, a substantial amount of research on online argumentation has focused mainly on knowledge representation issues in order to find proper knowledge formats for representing users' contributions. On the other hand, argument mapping researchers have neglected social and conversational aspects of online interaction. As consequence, argument mapping tools are object-oriented rather than human oriented, leading to the objectification and formalization of conversation around the knowledge map, as well as the loss of a range of meta-information about participants, the interaction process through which the content is generated and generated content. According to Clark and Brennan [1991] the lacking of this meta-information hinders free interaction and makes conversations less efficient [Clark and Brennan, 1991]. In reality, the availability of meta-information contained into conversational feedback does not only make the conversation more pleasant from the social point of view, but above all it facilitates the grounding process, i.e. the construction of shared understanding between participants, thus increasing the efficiency and effectiveness of a conversation [Clark and Brennan, 1991; Convertino et al., 2008]. This has negatively impacted on the use and widespread adoption of argument mapping tools as technologies able to mediate free interaction and communication.

Therefore, in this research, in order to retain the advantages offered by argument mapping tools but at the same time to improve their capabilities to mediate interaction, we propose a new technological solution, namely the Debate Dashboard. It can be defined as an augmented argumentation platform able to deliver real-time, visual conversational feedback to facilitate mutual understanding and improve users' performances.

In order to test our approach and, in particular the Debate Dashboard, a field test has been performed at the University of Naples Federico II. In general it is possible to state that the obtained results confirm the most part of proposed research hypotheses. Therefore, visual feedback effect mutual understanding and users' performances. In other words, it is possible to affirm that social and conversational feedback increases and supports mutual understanding among members of group A and impact on the quality of collaboration and of decision. In nutshell, mutual understanding, quality of collaboration and quality of decision of group A is significantly different from mutual understanding and users' performances of group B.

From SEM analysis is emerged that all visual feedback impact on mutual understanding and on users' performances, except Community feedback that does not impact on quality of decision and on usability. In addition, mutual understanding plays a crucial role as mediator and catalyst among visual feedback and users' performances, except among Absorption feedback and users' performances (Quality of Collaboration, Quality of Decision and Usability) and among Interaction feedback and Cohere Usability. What we did not expect that Interaction feedback affected negatively on Mutual Understanding, but this could be explained by two main reason: i. The design of visual widgets that provide this feedback is not appropriate and, thus, more analysis have to be performed, and ii. The reduced number of provided feedback respect to that individualized by Clark and Brennan [1991].

In conclusion, this study makes important theoretical and practical contributions. First, the study developed and tested a theoretical model of the influence of visual feedback on mutual understanding building among online distributed users involved in collaborative conversation mediated by argument mapping tools. To the best of the researchers' knowledge, no previous study have integrated argument mapping tools with visual feedback. Further, no previous researches has used common ground approach to improve argumentation technologies' mediation capabilities.

In addition, the conclusion that online collaborative tools should be able both to foster free communication and to aid a more structured knowledge organization has important practical implications. Indeed, our findings show that social interaction and knowledge organization are two crucial conditions for supporting successful online collaborative tasks, such as deliberation and decision making process. These two aspects should be considered as two *souls* of a same element that cooperate in supporting and ensuring effective distributed communication and collaboration. This has important practical implications, in particular for who develops collaborative knowledge management technologies. Indeed, through this research, we know that the above mentioned elements are crucial, but further analysis has to be performed to better understand how and in what “dosage” these two ingredients has to be mixed.

6.8 Limitation

Although this study makes several practical and theoretical contributions, it has numerous limitations which should be acknowledge.

The first limitation of this research is that participants were drawn from a single academic course. Consequently, the context is quite different from a fully open online community. This represents a significant limitation of this study, also because the belonging to the same groups means that some students already know each other and a first layer of common ground was developed. The impact of this limitation has been reduced through the randomization of groups. Another important consequence of it, is that the generalizability of findings are limited. Indeed, before the results of this study can be generalized should be replicated with other community of experts (i.e. doctors, engineers and so on).

The second limitation of this research is the size of samples. Indeed, the basic idea is to expand the samples in order to better measure the effectiveness and efficiency of visual feedback in mediate and support large discussion groups. This should allows us to obtain stronger and more accurate results.

The third limitation of this study is that we did consider in our analysis demographic variables that could be inserted in SEM models. The consideration of demographic variables, such as age, year of study, average exams, could give us further information about the use of visual feedback and, thus, on the impact of it on mutual understanding and users' performances. In other words, by controlling demographic variables, we could better understand the role of visual feedback on users' mutual understanding and performances.

The final limitation of this dissertation regards the use of Likert scale to collected data. Indeed, one of the main criticism is that Likert scale uses close-ended questions. In this case, the interviewee can choose among a limited range of alternatives and may be encouraged to give an answer without reflecting and personal involvement [Russo and Vasta, 1988]. Another problem is that the participants may be encouraged to give an answer though he/she has nothing to say about the topic. These shortcomings could lead interviewees to give responses not rational. In addition, as the items are presented sequentially, participants could give mechanic and always the same responses (so-called response set. In order to tackle this problem, we introduce some items with an opposing semantic tendencies to make evident eventual inconsistencies.

Despite the limitation identified above, this dissertation has provided several theoretical and practical implications. None of the limitations detract value and rigorous methodological used.

Appendix A
Literature review on Visualization Tools

In this appendix, we introduce a literature review on a sample of thirty visualization tools able to provide information about online community, its members, interaction process and generated content. We built our sample by using solely tools that have been implemented. Some of these visualization tools are available online and user can directly upload their data and produce graphic representations (for instance, see ManyEyes and/or Prefuse sites). The visualization tools selected and reviewed have been our benchmark for defining key features of visual widgets that compose the Debate Dashboard; in other words, we used them to "inspire" the design and in the implementation of a debate dashboard. We analyzed each of them on the basis of our proposed feedback to understand.

Table A1 shows all tools in our sample. This table represents the visualization tools by our defined feedback category, our proposed feedback sub-classes and implementation description.

Table A1. Review of Visualization tools

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
1	Babble (Erickson and Kellogg, 2000)	Interaction Feedback	Copresence Visibility	A cookie represents the conversation area and the marbles represent the users. The marbles of active people are represented near the center of the cookie, while ones of inactive people are represented near the periphery. Marbles outside of the cookie represent people in different conversation.
2	BulB (Mohamed *et al.*, 2004)	Interaction and Absorption Feedback	□	Stems represent each thread and their height represents how long they are active. The stem-head can represent either the development of thread (each line is a post) or user thread participation (each colour is a user).
3	Change treemap	Absorption Feedback	Structuring	A Treemap is a visualization of hierarchical structures. Treemaps enable users to compare nodes and sub-trees even at varying depth in the tree, and help them spot patterns and exceptions. Items are divided into categories, subcategories, and go on. This tool allow to visualize changes in the structure of the data
4	Chat Circles (Viegas and Donath, 1999)	Interaction Feedback	Copresence Visibility Cotemporality Simultaneity	The people are represented by coloured circles. They brighten when a user edits a post and they grow to accommodate the text inside them. They fade and diminish in periods of silence, though they do not disappear completely so long as the participant is connected.
5	Chat Circles II (Donath and Viegas, 2002)	Interaction Feedback	Copresence Mobility Visibility Cotemporality Simultaneity	The circles move around the screen simulating their movement between different topics in the chat. They leave a trace that fades over time.
6	Chatscape (Donath and Viegas, 2002)	Community and Interaction Feedback	Visibility Cotemporality Simultaneity Identikit	Chatscape introduces behavioural representation. Actions change the icon's appearance; these changes are driven by both the user's preferences and the judgement of the other participants.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
7	Comment flow (Offenhuber and Donath, 2008)	Interaction Feedback	Sequentiality (reply structure)	This tool allows visualizing communication behaviour. It considers three parameters: - the temporality of the network (through the opacity of the nodes), - one vs. two way communication, - quantity of information exchanged (through a marks along the edge).
8	CommenTree	Interaction Feedback	Sequentiality (reply structure)	Users are presented as orbs of different colours representing their gender, blue - males and pink - females. Each user has an icon associated with them depicting how much they comment. Less talkative individuals are shown with one speech bubble, whereas the most talkative have Three. Comment arcs are drawn between orbs when one user sends another a comment. When an orb receives a comment, it is lit brightly so that it can be easily determined who is currently sending and receiving communication. As users cease communicating they fade away creating a visual depth and allowing new communications to be viewed easier.
9	Communication-Garden System (Zhu, and Hsinchun, 2008)	Interaction and Absorption Feedback		Thread visualizer employs a floral representation to graphically depict the liveliness of a thread. The flower representation presents such statistic as number of messages (petals), number of participants (leaves) and time duration (height of stems). People visualize employs the same flower. The floral representation presents such statistic as number of messages (petals), number of discussions (leaves), and time duration (height of stems). In this representation the flowers have the faces.
10	Conversation Map (Warren, 2000)	Interaction and Absorption Feedback	Sequentiality (reply structure)	It represents social ad semantic network. In the former, the nodes represent participants and the links represent reciprocal quotations or responses. The shorter link, more frequently they reciprocated quote or response. The semantic network is a tree; it is plotted like a spider web, so that the child nodes of the root are drawn at a certain radius out from the root, the children of the children are drawn a bit further out in a ring around the children. If two nodes in the semantic network are connected, then empirically they have often been used in the same way in the archive.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
11	Coterie (Donath, 2002)	Interaction Feedback	Copresence Visibility Simultaneity Cotemporality	It represents two key elements: the activity of the participants and the structure of conversation. Users are represented as coloured ovals that bounce and became brighter when a user speaks. Some sentences appear on the screen and cohesive discussions have a single column, while divergent ones have entries scattered across the screen.
12	Email map	Interaction Feedback	Sequentiality (reply structure)	It shows all users' pictures in a circular way and when users talk each other, there is a link between them. The intensity of the relationship is determined by the intensity of the line.
13	Exhibit	Community Feedback	Profile	It allows visualizing and filtering information about members on geographic maps and timeline.
14	Flowergarden	Interaction Feedback	Sequentiality (reply structure)	Each participant is represented by a flower, with a petal growing on the flower in real-time as a new conversation is entered. The flowers of individuals who have conversed with one another are connected by green vines, and the closer two flowers are distanced from each other the more those people have spoken. The concepts discussed between all participants are laid out in the background according to their frequency of use.
15	ForumReader (Dave *et al.,* 2004)	Absorption Feedback	Structuring	It uses rectangles to represent each post in the discussion. Rectangle height corresponds to the length of the post. The message can be coloured with different colours to highlight attributes selected by users. It allows users to select a topic and highlight all of its posts or to provide a graded colouring of posts similar to a selected post (this systems uses keywords).
16	History Flow (Viegas *et al.,* 2004)	Absorption Feedback	Structuring	To each user is associated a colour and each his/her post is represented with a vertical line. The length of the vertical line indicates the amount of text. Connecting the different segments (intervention) of consecutive versions is possible to understand the evolution both of the map and of the individual intervention. The gap (i.e. that part of the text has no correspondence in later) indicates that there has been the elimination of the contribution. The major topics are represented thanks to the width of each flow.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
17	Loom (Donath, 2002)	Interaction Feedback	Sequentiality (Reply structure)	Each post is represented with a dot. The links existing represent the connections between sequential posts in a thread.
18	NewsGroup Crowd and AuthorLines (Viegas and Smith, 2004)	Interaction Feedback		**NewsGroup Crowd:** It is a scatter plot of each author is represented by circle and its size depends on the amount of created posts. The colour of each author's circle represents how recently authors have been active. **AuthorLines:** Month names are displayed at the top of the visualization panel. Vertical lines of circles represent weekly activity: each circle stands for a conversation thread to which the author has contributed during that week. The size of the circle represents the number of messages. Orange circles represent threads that were initiated by the author; yellow circles are threads started by other users.
19	PeopleGarden (Xiong and Donath, 1999)	Interaction Feedback	Sequentiality (Reply structure)	It uses a flower and garden metaphor. Users are represented by a flower. The longer they have been involved, the higher the stem. Initial postings are in red, replies in blue. Each thread is a garden full of flowers. The reply structure is represented through a bud on the answered petal.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
20	PostHistory and Social Network Fragments (Viegas *et al*., 2004)	Interaction Feedback	Sequentiality (reply structure)	**PostHistory** interface is divided into two main panels: the calendar panel on the left, which shows the intensity of email exchanges over time, and the "contacts" panel on the right, which shows the names of the people with whom ego has exchanged email. In calendar panel, each square represents a single day. The size of it represents the quantity of email received on that day. In contacts panel there are three visualization modes in the contacts panel: vertical, circular, and alphabetical. For the first and the second mode, the most frequent contacts are visually closest to ego. **Social Network Fragments** reveals the faceted contexts that people systematically create. It comprises of two different panels: the primary social network panel and a history panel. The history panel depicts each time slice as a two squares. The outer square represents the number of awareness connections that occur during that time period while the inner square indicates the number of knowledge ties.
21	SocialAction (Perer and Shneiderman, 2006)	Interaction and Absorption Feedback	Sequentiality (reply structure) Structuring Contextualization	It is a graph to represents networks. This tool allow to filter and to cluster the information
22	TagCloud (Hearst and Rosner, 2008)	Absorption Feedback	Relevance	A tag cloud is a visualization of words frequency. The size of the word corresponds to the quantity associated with that word. Whenever the mouse is over a word, information about the occurrences of that word and the context it was used in will be shown in a tooltip. Tagcloud allows users to compare two different bodies of text.
23	TheMail (Viegas *et al*., 2006)	Absorption Feedback	Relevance	The interface shows a series of columns of keywords arranged along a timeline. Keywords are shown in different colours and sizes depending on their frequency and distinctiveness. Yearly words (used the most used terms over an entire year) are represented as large faint words shown in background; while monthly words (the most distinctive and frequently used words over a month) are represented yellow and shown in foreground.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
24	ThemeRiver (Havre *et al.*, 2002)	Absorption Feedback	Relevance	It uses river metaphor. The river flows through time, changing the width to depict changes in the thematic strength. Themes or topics are represented as coloured currents flowing within the river. The river is shown within the context of a timeline and a corresponding textual presentation of external events.
25	TimeLine	Absorption Feedback	□	It uses a time chart whit month, day and hours; in this way it is possible to represent the events respecting chronological order.
26	TimePlot	Absorption Feedback	□	It is widget for plotting time series and overlay time-based events over them.
27	TimeVis	Community Feedback	Structure	It is a social network. A blue dot denotes a male person, whereas a red dot denotes a female. The edges are also coloured depending on the inviter's and invitee's gender. -female invites another female, we have a red edge. -male invites another male, we have a blue edge. -male invites female, we have a green edge. -female invites male, we have a yellow edge.
28	Treemap	Absorption Feedback	Structuring	A Treemap is a visualization of hierarchical structures. Treemaps enable users to compare nodes and sub-trees even at varying depth in the tree, and help them spot patterns and exceptions. Items are divided into categories, subcategories, and go on.

N°	VISUALIZATION TOOLS	FEEDBACK CATEGORY	FEEDBACK	IMPLEMENTATION
29	WikiDashBoard (Suh *et al*., 2008)	Interaction and Absorption Feedback		**Article dashboard:** that displays an aggregate edit activity graph representing the weekly edit trend of the article, followed by a list of the top active editors for that page. The top summary graph shows two trends: a gray line graph representing the edits made on the article and a blue bar graph denoting the edits on the corresponding “Talk” discussion page. The weekly edit activity graph of each editor on the right side of the dashboard enables users to investigate when the edits by that editor were made. A darker red bar denotes more activity in a particular week. Below the article edit summary, the active users of the article are ordered by the number of edits they made on the page and its talk page combined. **User dashboard:** the top summary graph shows the editor’s weekly edit activity. The summary graph is followed by the list of Wikipedia pages where the editor has made edits. The list is ordered by the volume of contribution and includes the corresponding article-editor activity graphs on the right side.
30	Wordle	Absorption Feedback	Relevance	A "Wordle" enables us to see how frequently words appear in a given text. The size of a word is proportional to the quantity associated with that word.

Appendix B
Post session questionnaire

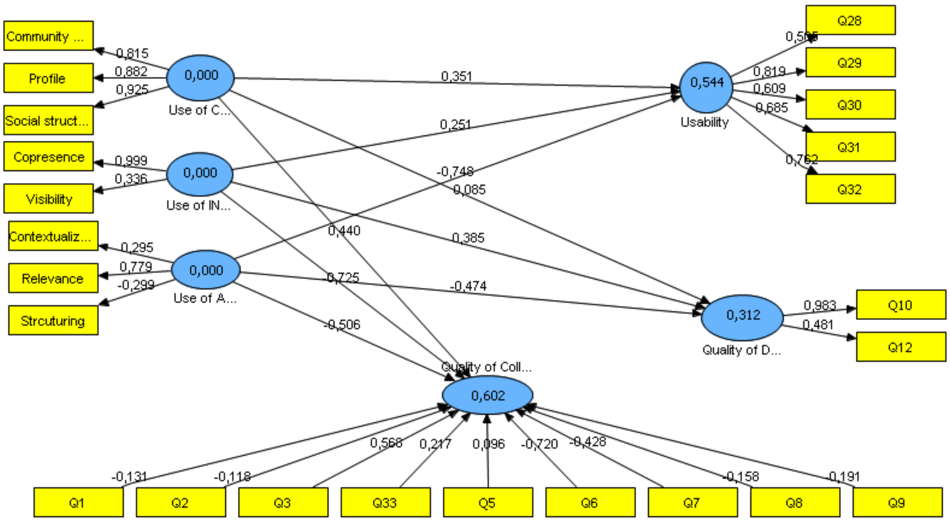
#	**Questionnaires items**	**Likert**
Q1	The interaction level developed during Cohere-mediated conversation was satisfying	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q2	I found the online discussion interesting and engaging	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q3	Collaboration was effective to solve assigned problem	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q4	I found it difficult to keep track of the conversation	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q5	The argument map was helpful in facilitating knowledge sharing among other team members	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q6	I shared my own knowledge about the task with my teammates	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q7	I found that my teammates have shared own their knowledge about the task	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree
Q8	The group developed a good amount of work	1 Strongly Disagree, 2 Moderately Disagree, 3 Somewhat Disagree, 4 Neutral, 5 Somewhat Agree, 6 Moderately Agree, 7 Strongly Agree

#	Questionnaires items	Likert						
Q9	The group made a good job	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q10	I think that, at the end of online debate, the group has a common position about the discussion topic	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q11	What is your initial decision before discussing with other group members?	1 Price Increases			2 Price Reduces			3 Price is Stable
Q12	What is your decision at the end of online debate?	1 Price Increases			2 Price Reduces			3 Price is Stable
Q13	What is group' s decision at the end of the discussion?	1 Price Increases			2 Price Reduces			3 Price is Stable
Q14	In general, I have not had problems to understand the meaning of other team members' posts	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q15	In general, I think that the other team members have understood my contributions without difficulty	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q16	I could easily understand (tell) what my teammates had done on Cohere	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q17	I could easily understand who has done what	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q18	I could easily say who is online on Cohere	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree

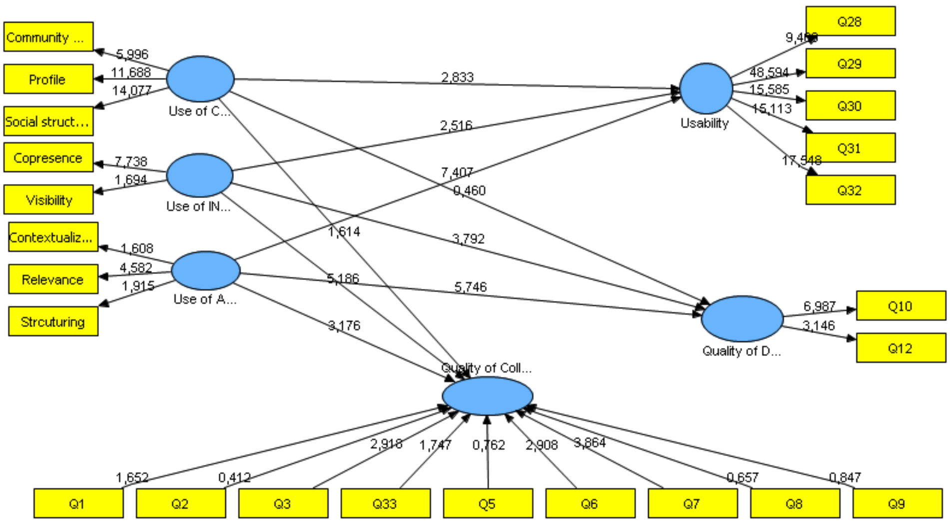
#	**Questionnaires items**	**Likert**						
Q19	My teammates and I developed better understanding about each other over the two weeks	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q20	My teammates and I developed shared understanding about the task over the time	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q21	I found online conversation is often redundant	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q22	I found there are many irrelevant posts respect the assigned task	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q23	Interaction with the system does not require a lot of my mental effort	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q24	I find the system to be easy to use	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q25	I enjoyed collaborating with my teammates using Cohere	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q26	I would enjoy working with my teammates again using Cohere	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q27	It was easy to communicate effectively given the tools available	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree
Q28	Cohere supports and facilitates collaboration among online users	1 Strongly Disagree	2 Moderately Disagree	3 Somewhat Disagree	4 Neutral	5 Somewhat Agree	6 Moderately Agree	7 Strongly Agree

Appendix C
SEM Graph

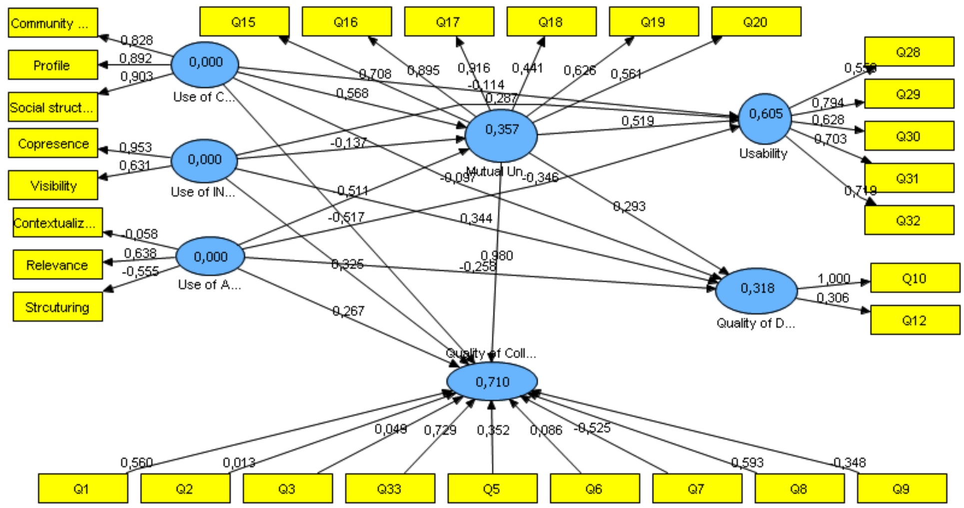
In this appendix, we present four screenshots that show results deriving from SmartPLS.



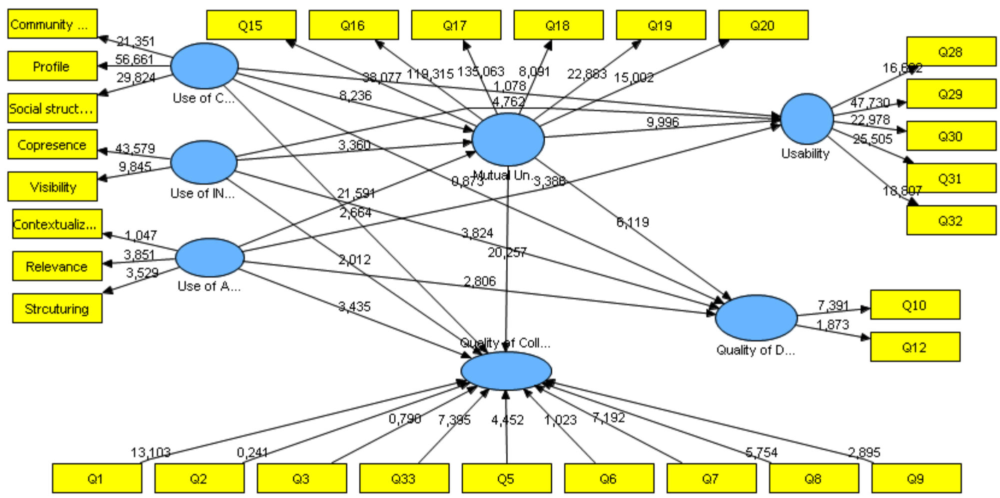
Simple Model – PLS Analysis



Simple Model – Bootstrapping Analysis



Mediated Model –PLS Analysis



Mediated Model – Bootstrapping Analysis

These models represent the two steps of procedure to perform mediation analysis to test the hypotheses that Mutual Understanding mediates the relationships among visual feedback and users' performances, namely Quality of Collaboration, Quality of Decision e Usability.

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