Misunderstandings in Global Virtual Engineering Teams: Definitions, Causes, and Guidelines for Knowledge Sharing and Interaction

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1. The problem of misunderstandings in Virtual Engineering Teams

Engineering is a collaborative effort aiming at both organizational and team member objectives. Collaborative work combines team member capabilities to perform complex tasks, which individual members will not be able to achieve on their own. Moreover, in the engineering process, team members learn from each other and mutually motivate each other. However, collaboration in engineering can also be complex, because it requires the involvement of different professions, with different goals, objectives and belief systems, and rarely do they share a common educational foundation (Draghici and Drahici, 2006).

The heterogeneous backgrounds of the participating professionals, the various professional interactions (among the team members, and with clients and suppliers), the pressure of time in attaining tasks, and the challenges that need to be met can generate various kinds of misunderstandings, leading to errors and conflicts. Despite all the new means of communication (like social software tools; see e.g. http://en.wikipedia.org/wiki/Social_software) and engineering conventions and standards (e.g. conventions for drawings, three-dimensional models, and ISO specifications), the problem of misunderstandings in engineering teams still remains. In fact, misunderstandings interrupt everyday activities and the anticipated patterns of interaction (Clases and Wehner, 2002). Many business decisions are made (and later regretted) due to a misunderstanding of the available information. In other words, engineering team meetings, which are assumed to provide a creative forum in which designers and researchers can interact and share knowledge, often are confronted with large complexities because of accumulations of misunderstandings (Weick, 1979).

In order to know how we can handle these problems, we need a better understanding of misunderstandings and their origins in virtual engineering team contexts. Virtual teams have been around for over 20 years (Tapscott and Williams, 2006), but it was only within the past 10 years that larger scale multi-office execution strategies for engineering began. The business model for many organizations in the next five years will have global execution at its core (McQuary 2003). Global engineering in the near future may even require collaboration of people from multiple sites, resulting in increasing problems of mutual understanding, especially if we take into consideration the multi-cultural environment of a virtual global team.

Organizations have begun to consider various strategies to reduce the cost of their capital projects. One such strategy is through globally competitive sourcing of engineering services. Companies are also keen to complete new facilities faster so they can release the final product to the market as early as possible. This leads to organizations focusing more on schedule driven projects. Also global virtual engineering teams can be favorably considering the project location so that organizations may locate engineering services close to the equipment, client and vendor locations.

In this context, a general definition can be adopted: *A Global Virtual Engineering Team is a group of geographically dispersed and potentially mobile individuals organized through communication and information technologies that need to overcome space, time, functional, organizational,* *national, and cultural barriers for the completion of a specific engineering task*. Besides, global virtual engineering teams have many cultural, economic, political, and technological aspects that must be addressed in order to be successful.

This chapter focuses on the communication aspect of collaboration. We make here the hypothesis that the condition for an effective collaboration (avoiding misunderstandings) is a common understanding of the situation (e.g. context, objects, goals and language), made possible by communication between the team members (Tee'ni, 2001). We start by giving general definitions of misunderstandings and a classification of their causes in global virtual engineering teams. We are then able to analyze misunderstandings in the concrete situation of the VRL-KCIP, and suggest guidelines and tools to avoid them. We conclude with ideas for further research.

2. Definitions and causes of misunderstanding

According to the Free Dictionary[1], misunderstanding is: (1) a failure to understand or interpret correctly or (2) a disagreement or quarrel. The same source gives other details in explanation of the term: Misunderstanding - putting the wrong interpretation on; synonyms: misinterpretation, mistaking. The term is connected with:

- Interpretation - an explanation that results from interpreting something;
- imbroglio - a very embarrassing misunderstanding;
- misconstrue, misconstruction - a kind of misinterpretation resulting from connecting the wrong meanings to words or actions (often deliberately);
- misreading - misinterpretation caused by inaccurate reading.

The definitions below underline the causes and the effects of misunderstanding in its different ways. The International standard ISO/IEC 11179-4 has an interesting view on misunderstanding: "Precise and unambiguous data element definitions are one of the most critical aspects of ensuring data share-ability. When two or more parties exchange data, it is essential that all are in explicit agreement on the meaning of that data. One of the primary vehicles for carrying the data's meaning is the data element definition. Therefore, it is mandatory that every data element has a well-formed definition; one that is clearly understood by every user. Poorly formulated

[1] http://www.thefreedictionary.com/misunderstandings

data element definitions foster *misunderstandings and ambiguities* and often inhibit successful communication".

Communication is a very important tool for managing an engineering team and for facilitating knowledge sharing among team members. During the communication process misunderstandings and errors can appear as a consequence of its communication complexity (Tee'ni, 2001).

Paek and Horvitz (2000) suggested an interdisciplinary taxonomy of communication errors based on four levels of coordination for grounding mutual understanding: channel, signal, intention, and conversation. For example, if uncertainty exists at the intention level, then there must be uncertainty at the conversation level since the conversation level builds upon the intention level. Likewise, it may be the case that uncertainty at the intention level is caused by uncertainty at lower levels. There cannot, however, be uncertainty at the channel level with mutual understanding at higher levels. Notice that when there is no uncertainty about joint understanding at any level, the utterance has been fully grounded.

At this point, it is important to note that what is not listed are "communication errors" that remain under the surface. For example, Blum-Kulka and Weizman (1998) classify "non-negotiated misunderstandings" in which speakers choose not to show that their intentions were misinterpreted. Instead, they choose to accept whatever interpretation the listener gave to their utterance. In such a case, it is unclear whether a communication error did in fact occur since the speaker has chosen not to treat the misinterpretation as an error.

Given that all the members of a team have been educated into their own ways of seeing and understanding the world, it is inevitable that there will be conflicts between their socially constructed realities. Kalay (2001) suggests three steps in resolving such conflicts to facilitate collaboration:

1. Recognize that different worldviews exist.
2. Develop means that can help each participant at least to understand if not to agree with the worldviews of the other participants.
3. Develop a consensual worldview that will recognize the legitimate concerns and goals of each participant and maximize the overall utility of the project.

Were professionals have different educational backgrounds, they often have different understandings of "common" concepts and events. On the one hand one word or issue can have more than one meaning, thereby allowing for different understandings by different interpreters. And on the other hand, two different words or issues can have the same meaning, thereby leading to miscommunication. The question is then: who establishes this meaning in a project team? Each of the participants has developed its own language to facilitate discourse within its own sub-culture, and much information in virtual teams is not explicit in meaning, i.e. its meanings must be inferred from contextual and experiential evidence. A shared understanding relies on the exchange of information and mutual agreements as to the relevance and meaning of shared information (Citera et al., 1995). Within a multi-disciplinary team, where engineers from multiple organizations work together supported by computer-based systems, design occurs as a social process of reaching a “shared understanding” (Toye et al., 1993) of the design problem, requirements and process itself. The success of collaborative design thus depends on two factors: 1) social interaction and 2) knowledge sharing. Concerning social interaction, design engineers bring with them their own language, jargon and perspectives to the design team, which may result in incompatible viewpoints among team members probably resulting in ineffective collaborative, suboptimal decision-making and impaired projects (Hill et al., 2001). Moreover, team meetings might be unproductive if information is brought to bear that is of relevance to only a few individuals. Some members may use too much jargon in their communication, separating their voice undesirably from the group’s voice. While one cannot ignore the organizational and social barriers of getting to a shared understanding among team members, identifying barriers to overcome offers a crucial first step (Hill et al., 2001).

Concerning knowledge sharing, effective multi-disciplinary shared understanding can be enhanced through a combination of representational approaches, each capable of supporting one component of the meaning. For instance, Kalay (2001) has chosen objects, project and context as the domains of such comprehensive semantic representation. By promoting shared understanding, it will facilitate evaluations and negotiations that are based on explicit facts and assumptions.

All these definitions of misunderstandings, the groundings, and mentioned causes can be integrated in the six semiotic layers mentioned by Stamper (1973 and 1985). These layers and their causes of error are summarized in Table 1.

Table 1. Misunderstanding layers and their causes

Semiotic layer	Misunderstanding causes
Technical layer: the physical media that carry the messages	Incomplete and distorted sounds, inference of noise, distortion or corruption of files and text
Empirics layers: Human use patterns of messages	Unclear speech and accents, lack of redundancy and feedback in communication.
Syntactic layer: The ways how	Poor and incomplete coding of message and

information is coded and formalized	knowledge; use of nonstandard codes or codes that are uninterpretable by the target audience.
Semantic layer: The meaning of messages in a given linguistic context	Use of complex jargon; unclear expression of vision; (over) complex arguments; information overload
Pragmatic layer: The behavior a certain message wants to initiate at its human receiver	Conflicts of interests; distorted interpretations because of biased views.
Social norms layer: The social contextual rules that govern or enable effective communication between message exchanging people	Differences of behavioral norms; nonverbal messages may have different meanings among represents of different cultures

3. The case of a global virtual engineering team: VRL-KCiP

This section presents the causes of misunderstanding in global virtual teams together with some examples from our own VRL-KCiP experiences (www.VRL-KCiP.org). The VRL-KCiP is a so-called network of excellence established by the European Committee in the context of its 6th Framework Program. It involves over 300 researchers in more than 20 EU states, who aim at establishing a virtual platform for exchanging their knowledge among each other and for disseminating this knowledge to EU enterprises.

The VRL-KCIP explicitly aimed at developing a Knowledge Management System (KMS) for its community, in order to:

- Facilitate VRL members and industry to find information and people within the VRL network (technology transfer),
- facilitate collaborative work within VRL-KCiP, and between VRL-KCiP and industrial users,
- facilitate collaboration and common understanding among industrial users,
- enable the sharing of information in "the right" context and disseminate the same meaning to the different participants,
- enable each member to contribute the knowledge related to his own expertise as part of a larger whole,
- enable each member access to and understand in detail the part of the content that they need to use,

- enable each member to understand the scope of the knowledge that can be delivered by other partners involved in the network.

A specific task was dedicated to specify the services of the KMS from the users' perspective. The work was done in a collaborative work between several members of the VRL-KCiP. During 6 months, the work group met in regular Video conferences, about once a week, and during a workshop. Use cases were used as a method to identify the KMS functional requirements.

In order to define a system that would be really useful and actually used by the VRL-KCiP members, the team which was dedicated to the KMS specification concluded that the system usability is crucial - usability in the meaning of ease of use, but also in the meaning of providing an adequate functionality. They stated that even if many exciting functionalities can be imagined, it is of specific importance to provide usability in the basic areas of posting/editing and searching/browsing information. The group then specified that:

- When posting information, knowledge and documents, the member should not be restricted to one hierarchy of structuring or defining concepts, specifically since the members of VRL-KCiP come from different cultures and have different ways of defining their competence. In addition, the relations between items should be possible to change when new insights emerge.
- When searching/browsing, the search should not be restricted to following one path, but it should be possible to access information from various "directions", i.e. going from a competence key word to finding labs working in the key word area to finding out who these labs collaborate with to finding other key words related to that collaboration to finding other labs working in the areas of these new key words, to finding the location of these labs to finding out what other labs or companies are co-located in that area etc.

The VRL-KCiP KMS was then developed using the SmarTeam® Product-Data-Management application. The basic operating principle of SmarTeam is that users create tree structures. They characterize each item's attributes, author identification, right to access, and other factors in profile cards, and store related documents into a secure vault. Users can search for information by defining queries, by navigating through profile cards, or by navigating through the on-screen tree description. Trees may be product structure, or document folders. Objects in trees, whatever their type, may be visualized, redlined, annotated, published, sent through a release or other process, or exported[2].

The necessary underlying formal (tree) structure of this platform lead to a very difficult access to the specific items in the KMS for most of the people. These have been adjusted by creating specific links in the VRL-KCiP web page. The meaningful management of the content, though, still remained complex. People were invited to send in their CVs and research interests, and this quickly resulted in a very extensive list of expertises. This list had over nine layers of subdivisions.

It was also very difficult to motivate people to submit their CV and maintain the content, and alternative attempts for people and expertise finding were developed, like topic mining of CVs and all kind of co-authoring and communication tools. The VRL-KCIP management agreed that their members should be helped to motivate global virtual engineering teams. Some of the recommendations included developing project incentive programs. Informal meetings, especially at the annually held general assembly meetings of the VRL, were very efficient for solving misunderstandings and conflict situation. It is important to understand the items that people value and also it is better to leave detailed decisions regarding appropriate rewards and recognition to the local teams. This refers to pragmatic roots and norms that should be implemented in the VRL. The managers that have gained experience in global virtual teams' projects mentioned that they have figured out ways to overcome the challenges and have improved drastically on their project performance metrics such as engineering cost, construction cost, engineering time, overall project delivery time, engineering quality, and construction quality. Even though the word 'virtual' is found in global virtual engineering teams, some element of face-to-face interaction is critical and cannot be avoided.

Finally, one of the most critical failure factors was a lack of understanding of local work practices, cultural differences, and language issues. Team research and goal setting theory has demonstrated the importance of establishing a common purpose among team members and then working towards this purpose to increase team effectiveness (Hacker and Lang, 2000). Some of the drivers identified by international managers in companies were to gain large supply of younger engineers, gain work overseas, and make projects economically viable.

We summarize our findings in the VRL-KCiP in Table 2.

[2] www.coe.org

Table 2. Analysis of misunderstanding within the VRL-KCIP

Semiotic layer	Application to the VRL-KCiP
Technical layer	In order to cope with this kind of misunderstanding, the SmarTeam® software was available via the VRL-KCIP Intranet.
Empirics layers	SmarTeam® management standardizes ways of submitting documents and content.
Syntactic layer	Hierarchies in the SmarTeam® system for content maintenance and querying. Results in a very complex structure; later solved by more flexible search mechanisms
Semantic layer	The multi-disciplinary and multilingual context of the VRL easily results in confusions, for instance the use of complex jargon with different meanings among the participating groups.
Pragmatic layer	VRL management has to put much energy on letting people submit proper content to the smart team system, but this did not by itself result in more collaboration between participating research groups. The informal circuits were essential for developing collaborations
Social norms layer	Differences of behavioral norms; nonverbal messages may have different meanings among represents of different cultures

4. Avoiding communication misunderstandings

We are now going to expose advices for avoiding communication errors in order to facilitate collaborative work in engineering teams. The theory, as well as the VRL-KCiP experiences, indicate that solutions for misunderstandings in global virtual engineering teams need to consists of (1) general communication guidelines to solve problems related to the different cultural and linguistic background, and (2) data or knowledge sharing tools.

4.1. General communication guidelines

Context communication is everything. The English language is full of meaning nuances; a word may have multiple meanings based upon the context that it is used.

Here are some advices (Draghici, 2007) to help you improve your cross-cultural communication skills:

- Slow Down **-** Even when English is the common language in a cross-cultural situation, this does not mean you should speak at normal speed. Slow down, speak clearly and ensure your pronunciation is intelligible.
- Separate Questions **-** Try not to ask double questions such as, “Do you want to carry on or shall we stop here?” In a cross cultural situation only the first or second question may have been comprehended. Let your listener answer one question at a time.
- Avoid Negative Questions **-** Many cross cultural communication misunderstandings have been caused by the use of negative questions and answers. In English we answer ‘yes’ if the answer is affirmative and ‘no’ if it is negative. In other cultures a ‘yes’ or ‘no’ may only be indicating whether the questioner is right or wrong. For example, the response to “Are you not coming?” may be ‘yes’, meaning ‘Yes, I am not coming.’
- Take Turns **-** Cross-cultural communication is enhanced through taking turns to talk, making a point and then listening to the response.
- Write it Down **-** If you are unsure whether something has been understood write it down and check. This can be useful when using large figures.
- Be Supportive **-** Effective cross-cultural communication is in essence about being comfortable. Giving encouragement to those with weak English gives them confidence, support and a trust in you.
- Check Meanings **-** When communicating across cultures never assume the other party has understood. Be an active listener. Summarize what has been said in order to verify it. This is a very effective way of ensuring accurate cross-cultural communication has taken place.
- Avoid Slang **-** Even the most well educated foreigner will not have a complete knowledge of slang, idioms and sayings. The danger is that the words will be understood but the meaning missed.
- Watch the humor **-** In many cultures business is taken very seriously. Professionalism and protocol are constantly observed. Many cultures will not appreciate the use of humor and jokes in the business context. When using humor think whether it will be understood in the other culture. For example, British sarcasm usually has a negative effect abroad.
- Maintain Etiquette **-** Many cultures have certain etiquette when communicating. It is always a good idea to undertake some cross cultural awareness training or at least do some research on the target culture.

Cross-cultural communication is about dealing with people from other cultures in a way that minimizes misunderstandings and maximizes your potential to create strong cross-cultural relationships. The above tips should be seen as a starting point to greater cross-cultural awareness.

4.2. The role of data or knowledge sharing tools in reducing misunderstandings

The simple fact that the participants of a design team cannot meet physically because of the distance, lead engineering companies to use new tools. Among them we find shared spaces, video conferencing, and shared product databases (PDM). But, as we described in sections 2 and 3, new difficulties appear that were less apparent in the past, i.e., cultural differences which may lead to misunderstandings (Boujut, 2002).

In fact, tools which permit to share product representations (numerical models for instance) can help engineers all to have the same technical information, and to coordinate during the collaborative design work. Boujut and Blanco (2003) for instance observed that the design participants of a project were coordinating their activity up to a certain extent by means of these representations. But when describing cooperative design processes, these authors also showed that this cooperation was fairly incomplete and far from systematic. This led to some crisis during the process. Their interpretation (validated by interviews with the designers) is that the representations involved were quite poor and not adapted to the context of use. More precisely the information required was not present although it existed somewhere else. They then drew the conclusion that there is a need to provide means for developing a more systematic co-operation, and to provide more relevant information to the participants earlier in process.

This is contradictory with what PDM vendors claim (Kalay, 2001): the idea according to which by providing a single, shared representation, there will be less need for individual disciplinary translations, and that interpretation will also be enhanced if the semantic relationships between the various objects are represented explicitly. While automation was intended to eliminate human errors, it seems that often automation itself becomes an underlying cause of human error (Shu and Furuta, 2005). Increasing the level of automation has resulted in both system performance and human interaction problems (Klein, 1997).

We can then summarize our point of view on the actual devices used during cooperative design phases by following Kikin-Gil (2006: 77): "computers and mobile devices […] are built around tasks and functions rather than around people and behaviours." In order to improve this situation, two directions could be followed. On one hand, eliciting domain expert knowledge to reach a shared understanding, and on the other hand providing computer-mediated-communication tools (Barnes, 2002) to improve human-human interactions.

Eliciting domain expert knowledge to reach a shared understanding (Kalay, 2001)

Different kinds of tools aim at eliciting domain expert knowledge: case bases, issue-based systems, repositories of shared practices, rule-based expert systems, and thus aim at highly rich semantic knowledge sharing. Examples here are:

- *Case bases*, which aim at inferencing and interpreting by providing comprehensive referential information, including contextual data. Such references inform the interpretive process. However, while case-based design representation of references is a powerful descriptive tool, it is insufficient, in and of itself, to convey meaning: it lacks the particular frame-of-reference of the specific design it acts as a referent for.
- *Issue-based systems* aim at providing explicit representation to capture the deliberative aspects of the design decision-making process. This representation describes design issues, and arguments in favor of or against the proposed design actions. These systems have helped explicate and understand the deliberative nature of the design process, but suffer from the inherent difficulty of encoding design knowledge in computational constructs. Therefore, they tend to work well only in very restricted domains,
- *Rule-based expert systems* come from a conceptual framework developed by artificial intelligence researchers. It relies on the hypothesis that the reasoning of an expert can be represented in the form of rules. But what may appear to be a rule to one professional may not be so for another professional within the same discipline, and is likely to be completely incomprehensible for someone from another discipline.

Favouring human-human interactions

According to Hulnick quoted by Powell et al. (2004: 11), “if technology is the foundation of the virtual business relationships, communication is the cement”. We observed this phenomenon within a healthcare network (Benard et al., 2006). This network, composed of 190 members, includes mainly private health professionals, as well as hospital workers and other actors in the medical and social fields. Its objective is to carry out all activities such as prevention, care, services, training and research for the benefit of elderly people suffering from cognitive disorders. The only relevant computer-based tool here on the market is dedicated to sharing patient’s data. So, even if the field is different (healthcare instead of engineering), the situation faced by the members is the same: they are remotely located, they come from different cultural or organizational backgrounds, and they want to build something together (here this is a care trajectory, and good care practices). After one year and a half observation, we noted that in many cases the conversations between the members of the network during the meetings were not task-centred. We also demonstrated that even conversations which are not directly related to problem-solving play a relevant role in the life of the team; they should therefore not be neglected and must, on the contrary, be taken into account in designing a tool favouring cooperation within a network. These exchanges seem to be essential because they create a common sense of identity between all the members having different professions, and enable them to get to know each other better, which is a prerequisite to avoiding misunderstandings.

But Information Systems for Virtual Engineering Teams often do not take into account exchanges of this kind; they focus on data, information and document management functions relating directly to the ongoing task. What is produced during conversations is therefore generally neglected. From our point of view, based on our empirical findings, they should, on the contrary, be taken into account in designing a tool favouring cooperation in the everyday activities of a virtual team. Besides, it would certainly be interesting to be able to trace previous exchanges in order to make full use of the information available and to be able to assess the efficiency of the work carried out by the network. We therefore claim that the *so-called social software tools* like co-authoring, people finding, tagging and community building tools, which focus on building efficient conditions for knowledge sharing could be very useful to support communication between virtual teams.

5. Conclusion

We summarize the means of coping with misunderstandings in global virtual engineering teams in Table 3.

Table 3. Human and IT tools for misunderstanding handling

Semiotic layer	Misunderstanding roots	Human guidelines	Tools
Technical	Incomplete and distorted sounds, inference of noise, distortion or corruption of files and text	Face-to-face presence at informal meetings	Appropriate networks and social-software
Empirics	Unclear speech and accents, lack of redundancy and	Slow down; Take turns;	Adequate usability of the software and

	feedback in communication.	Avoid slang	tools
Syntactics	Poor and incomplete coding of message and knowledge; use of nonstandard codes or codes that are uninterruptible by the target audience.	Avoid negative questions	Data items and document systems (Ontologies, PDM for instance)
Semantics	Use of complex jargon; unclear expression of vision; (over) complex arguments; information overload	Separate questions Write it down Check meanings	Case bases; Issue based systems; Rule-based expert systems
Pragmatics	Conflicts of interests; distorted interpretations because of biased views.	Check meaning	Sufficient motivation to contribute to knowledge bases and initiate collaborations were possible (according to knowledge-base information) Social software
Social norms	Differences of behavioral norms; nonverbal messages meaning differences	Be supportive; Watch the humor; Maintain etiquette	Correct representing of exchanging and communication norms in social software and administrative tools

Identifying when design teams have reached a shared understanding or not could be (1) an important management aid for example, by helping to detect and diagnose non-functioning design teams, (2) an advancement in understanding how design teams acquire and maintain their collective identity, and (3) a means for understanding the evolution of information needs in design teams. Currently, no well developed tool exists for identifying the level of understanding and especially detecting misunderstanding and its potential risks with regard to this in a global virtual engineering team. This paper has argued for the urgency to develop such a tool, and we have given an elementary framework to further build such a tool by further literature research, survey studies (also to know more precisely the business magnitude of this problem), possible experiments of such tools, and making these tools part of common project management practices for virtual teams. Some first attempts for such research have already started in the field of off-shored IT development (Kernkamp, 2007), and the field of manufacturing and product engineering will soon have to follow.

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