PRELIMINARY EXAMINATION OF ICT COLLABORATIVE DESIGN AND MANAGEMENT IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

Information and Communication Technology (ICT) is becoming more comprehensive and more integrated into the design and management phases of the construction industry. Not only are increasingly sophisticated electronic tools being widely used to assist construction professionals design and manage buildings - ICT is making significant contributions by assisting these people to work in virtual, electronic environments. As a result of the application of these enhanced ICT tools there is a trend to move away from co-located teams to virtual team collaboration. The operational differences which result from the use of different electronic communication media and its impact on generic skills on design and construction professionals have been the basis for the research reported in this Cooperative Research Centre Construction Innovation (CRC-CI) paper. The outcomes of this research include the development and mapping of generic skills profiles for virtual design teams. The research findings also describe changes in generic skills profiles between different operational states (low bandwidth-high bandwidth). The paper links our research findings with literature relating to design teams and processes, virtual teams and the generic skills required to effectively participate in these teams. The conclusions of our research indicate that design team participants require 'appropriate skills' to function efficiently and effectively, and that the introduction of ICT reinforces the need for ongoing skills mapping and measurement.

Keywords: design teams, generic skills, virtual teams.

INTRODUCTION

Recent developments in networked three dimensional (3D) virtual worlds, and the continuing development and implementation of high bandwidth information and computer technologies (ICTs), have the potential to dramatically improve collaboration in the construction industry (Gameson and Sher 2002). However this shift brings with it a need to understand the non-technical skills of construction design professionals and to profile the changes in different collaborative environments.

It is important to note that this paper documents part of a larger focus on ICT implementation in design/construction teams. The host research project focuses on the early stages of construction/design collaboration in which the designs for a

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structure are created, developed and revised. The research project described here investigates three aspects of collaboration in virtual environments: processes, models and generic skills.

This paper begins to explore those **people** issues present within the generic skills component of the research project, and the extent to which they contribute to the effectiveness of virtual teams. It presents background literature on the issues of teamwork, virtual teaming, and generic skills involved with teamwork. These themes are examined in the environment of early design from the perspective of a broad range of industries and teamwork research, to give an understanding of the movement from co-located to virtual teams.

There are two main drivers for the increasing uptake of ICTs in the construction industry:

1. The environment and operations of the construction industry has changed to more collaborative contractual arrangements in the form of alliancing and partnering (Love *et al.* 2002). This increase in alliancing creates a greater need for instant and reliable information and communication transfer between distributed parties.
2. The increase in alliancing and partnering has allowed for longer term arrangements between construction industry partners, which promotes a larger long term investment in communication technology. Investing time and money in new computer hardware and software is more attractive if such technologies can be used on many projects, with the same people.

While construction project partners are being driven towards changes in collaboration practices, there are challenges which need to be overcome. The most salient challenge is attempting to recreate within the virtual paradigm those aspects identified as being advantageous/facilitatory within co-located teams. One such aspect is the nonverbal communication between team members (monitoring body language and interacting according to these visual cues) which is a difficult issue for those creating higher bandwidth ICTs. This paper links literature on generic skills with that of design and virtual design collaboration. This literature and the preliminary results of the experimental study provide evidence that there is need to form a greater understand of the role of non-technical skills within design collaboration and how non-technical skills profiles may alter when high bandwidth technology service co-located designers.

AIMS

The aims of this paper are to:

1. Present and highlight literature which discusses the factors relating to co-located and virtual teams, design teams and generic skills. Then, through the literature, to draw conclusions about how generic skills may be affected through the movement of teams from co-located to ‘virtual’ interaction, and,
2. Pilot a framework for the analysis of design teams using video data of design team members collaborating face-to-face and using ICT.

These aims are examined in the context of early design from a broad range of industries.

BACKGROUND: THE CHANGING FACE OF DESIGN /CONSTRUCTION TEAMS

Industry is becoming evermore globalised as organisations endeavour to streamline and optimise their operations. It is debateable whether an organisation would resource a specific process internally if it were economically advantageous to outsource it. Also, only when ideas are shared and worked, may delays be avoided and superior products eventually created (Maher, Simoff and Cicognani 2000). However a move towards alliancing and partnering has resource implications, particularly time and money. The costs associated with convening a co-located team meeting in such circumstances include travel and accommodation.

TEAMWORK: WHAT IT MEANS TODAY

Teams are a cluster of two or more people usually occupying different roles and skill levels that interact '*…adaptively, interdependently, and dynamically towards a common and valued goal*' (Salas, Burke and Cannon-Bowers 2000: p, 341). They are the vehicle for the process of collaboration (Beyerlein *et al.* 2003). This process has changed dramatically in the past two decades with the introduction of ICTs, with the majority being facilitated through the Internet. McDonough III et al (2001) distinguish between the following team configurations:

- **Co-located -** comprised of individuals who work together in the same physical location and are culturally similar.
- **Virtual -** comprised of individuals who have a moderate level of physical proximity and are culturally similar. One example is team members who are in the same building but on different floors.
- **Global -** comprised of individuals who work and live in different countries and are culturally diverse (Mcdonough Iii, Bahn and Barczak 2001).

As clients of construction and design companies demand more efficient and higher quality services, use of diversely located team members on projects may increase (Kimble, Li and Barlow 2000). The need for efficiency (Kayworth and Leidner 2000) and group interaction has lead to increased partnering between companies (Love *et al.* 2002). Due to differences in location, team members now increasingly use electronic media to communicate ideas and designs (Jaafari and Tooher 2002).

GENERIC SKILLS

Generic skills are defined by Salas et al (2000: p, 344) as, *'…the knowledge, skills and attitudes that a team member possesses when completing a task or communicating with fellow members, whether in a co-located or virtual environment'*. Generic skills influence both individuals and teams; they are skills which are *'…transportable and applicable across teams.'* (Salas, Burke and Cannon-Bowers 2000: p, 344).

The focus of this study is the way generic skills manifest themselves in a design team and how a generic skill profile may change when the medium for team interaction is altered through the adoption of ICTs. A list of generic skills drawn from teamwork literature (Cannon-Bowers *et al.* 1995) (Table 1) has been used as basis to study non-technical skills in design teams.

Table 1: Integrated skills (as adapted from Cannon-Bowers et al 1995 (Salas, Burke and Cannon-Bowers 2000).

Core Generic Skills	Definition	Sub skills
Adaptability	The use of compensatory behaviour and reallocation of resources to adjust strategies based on feedback	• Flexibility • Compensatory behaviour • Dynamic reallocation of functions
Shared situational awareness	When team members have compatible mental models of the environment within and outside of the team.	• Orientation • Team awareness • System awareness
Performance monitoring and feedback	Ability of team members to give, seek, and receive task clarifying feedback.	• Performance feedback • Acceptance • Mutual performance monitoring • Procedure maintenance
Team management: Project management/leadership	Ability to direct and co-ordinate the activities of other team members particularly pertaining to performance, tasks, motivation, and creation of a positive environment.	• Task structuring • Motivation of others • Goal setting • Goal orientation
Interpersonal relations	Ability to optimise the quality of team members' interactions.	• Conflict resolution • Assertiveness • Moral building
Co-ordination	Process, by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronized and completed within established temporal constraints.	• Task organisation • Task interaction • Timing
Communication	Information exchange between members using the prescribed manner and terminology.	• Information exchange • Consulting with others
Decision making	Ability to gather and integrate information, use sound judgment, identify alternatives, select the best solution, and evaluate the consequences.	• Problem assessment • Problem solving • Planning • Implementation

The issue of the transfer of these skills to the virtual environment in many respects is unknown. The factors associated with the need to retain access to visual prompts acknowledged as important in co-located meetings have in part been addressed by the technology but there still remain unanswered questions concerning the form and presentation of the generic skills in the virtual domain. This study addresses a range of these issues.

APPROACH ADOPTED

Digital video recording was used as the method of data collection for this study. The advantages of video recording participants include: the ability to review interactions and behaviours, the ability to compare different coders' or viewers' interpretations, and the potential for the medium to become a replacement for live observation. The main operational issues, when video recording procedures, are 'capture setup' and analysis of the video (Guerlain *et al.* 2004).

The video analysis was conducted using ethnographic video analysis software. Noldus Observer Pro is a *'…manual event recorder for the collection, management, analysis and presentation of observational data…of humans and animals'* (Burfield,

2003: p, 21). The software allows the researcher to view live behaviour or recorded video data, and score the frequency of specific behaviours, as well as how these behaviours interact with each other or independent variables.

Video data was collected from two forms of collaborative design teams:

1. Traditional collaborative design using those communication and design tools currently employed by the design team members. These included simple face-to-face meetings, phone, fax, and email.
2. Virtual design utilising a shared electronic whiteboard (E-Whiteboard) which facilitated the sharing of drawings, images and text. It also employed synchronous speech and visual communication via a web camera.

An initial comparison of the two forms of collaborative designs was conducted using a coding system to distinguish the dimensions of generic skills, interactions and communication technique. This initial comparison also served to confirm the effects of virtual technologies as described by the literature.

While designers in the co-located condition were familiar with their surroundings and with the techniques involved in their collaborative design sessions, virtual design team participants required training and familiarisation with the functions and use of the new collaborative software. Once designers were suitably conversant with the software, design sessions began. The designers, an architect and an engineer, were asked to collaborate on a design on which they were currently working.

These sessions were conducted in the architect's offices in Sydney for the first stage (in situ conditions), and at Sydney University for the second (laboratory conditions).

PROPOSED MODEL FOR THE ANALYSIS OF GENERIC SKILLS IN LOW AND HIGH BANDWIDTH DESIGN TEAMS

We present the three frameworks of the coding scheme which will encompass the interactions between design collaborators. The Generic Skills Framework allows analysis of those non-technical skills which facilitate teamwork. Bales's Interaction Process Analysis (Bales 1951) allows for the analysis of the interactions between design team members, so that aspects such as decision making, communication and control may be examined. The Communication Technique Framework (Williams and Cowdroy 2002) looks at the techniques which the designers use to communicate during design collaboration. At this pilot stage of the study we will only analyse the video data using the single frameworks compared with the operational conditions without attempting to distinguish how these frameworks may intertwine.

GENERIC SKILLS

Each of the generic skills for teamwork, (described in Table 1) has been adapted into an analysis framework for the purpose of measuring the activity. This framework (Table 2) lists the observable behaviours to be measured to provide an indication of the utilisation of generic skills.

Table 2: Coding scheme for examining generic skills within collaborative design teams

Generic Skills	Observable Behaviours	Example
Adaptability	Recognises areas for improvement in design or solution	"Maybe I should change the size of X"
	Directs attention of the designer to a possible improvement for the design or solution	"Maybe you could change the size of X"
	Physically fixes or improves a design within 10 seconds of a flaw being nominated	
Shared Situational Awareness	Explains a design/solution	"This bit represents that service area"
	Asks for confirmation on a design/solution or aspect	"So this is the service area here?"
	Asks a question regarding a design/solution or aspect	"Where is the service area?"
	Finalises a design/solution	"OK that's that drawing done"
	Distributes relevant written or physical information	Example?
	Identifies future problems	"If X goes there it may become a problem in colder seasons"
	Uses anticipation to complete other team member's sentences. Usually followed by agreement from the team member	Example?
	Identifies a possible source of information	"John was working on this, maybe he knows the dimensions"
Performance Monitoring and Feedback	Questions or asks for a description of a task	"What scale are you going to sketch X at?"
	Provides comment on the appropriateness of a current or completed task, or a design either through agreement/disagreement, suggestions, or opinions (More general; overall comment)	"I think this is good, really good"
	Asks for feedback or confirmation on task	"You're drawing X at a ratio of 100:1 aren't you?"
	Explains a task	"I created a cross sectional drawing at the service level"
	Checks the outcome of a design/solution against the problem	"OK the size of the service area is in line with the brief"
Leadership/Team Management	Communicates the instructions and standards described in the design brief (formal)	Reads from brief
	Suggests a new task	"I think we should make a new drawing of section X"
	Gives priority to tasks	"We should draw a cross section first"
	Assigns tasks to team members	"OK you can do that and I will do this"
Interpersonal Relations	Spontaneously asks a team member for their opinion on a task or design	"Hey Pete, what do you think of X"
	Interrupts another team member with a statement which goes against what the member is expressing or changes the focus	Example?
	Conflict/conflict solving	Arguing/Taking control of an argument
	Joking, gossip/non-design discussion	"What are you doing after work?"

	Polite remark	"Thanks", "Sorry"
Co-ordination (task related)	Checks or monitors the progress of tasks against time	"We have to finish X by the end of the day"
	Checks or monitors workload against time	"OK you have 10 minutes to finish X"
	Asks a question regarding an artefact/technical problem	"Where is that drawing going?"
	Explains the presence or destination of an artefact/technical problem	"I am putting X over here with the other drawings"
Communication	This is better measured by the Bales IPA, as most of the behaviour within a team could be interpreted as communication	
Decision Making	This is better measured by the Bales IPA, which has a system for the measurement of decision making	

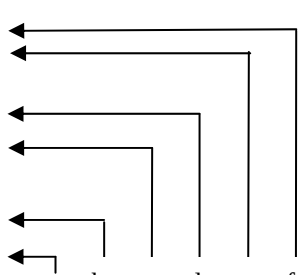
BALES'S INTERACTION PROCESS ANALYSIS (IPA)

Bales's Interaction Process Analysis (IPA) allows users to classify *'…direct, face-to-face interaction'* of a group of people engaged in a task (Bales, 1951: p, 5). The IPA provides a set of categories which are generic in nature and represent team/human interaction (Bales 1951). As Bales (1951: p, 31) explains *'The observation of social interaction and its situation is the common starting ground for all of the social sciences'*. The coding scheme, developed for this study, is shown in Table 3.

Bales' IPA has been used extensively in previous research because it facilitates an appreciation of the interaction and communication between team members in a range of environments.

Table 3: The interactions present within teams and their description [adapted from Bales (1951)].

		Interactions	Description
E	A	Shows solidarity	Raises other's status, gives help, reward
		Shows tension release	Jokes, laughs, shows satisfaction
		Agrees	Shows passive acceptance, understands, concurs, complies
	B	Gives suggestion	Direction, implying autonomy for other
		Gives opinion	Evaluation, analysis, expresses feeling, wishes
		Gives orientation	Information, repeats, clarifies, confirms
	C	Asks for orientation	Information, repetition, confirmation
		Asks for opinion	Evaluation, analysis, expression of feeling
		Asks for suggestion	Direction, possible ways of action
	D	Disagrees	Shows passive rejection, formality, withholds help
		Shows tension	Asks for help, withdraws out of field
		Shows antagonism	Deflates other's status, defends or asserts self.



KEY

a = Problems of communication
b = Problems of evaluation
c = Problems of control
d = Problems of decision
e = Problems of tension reduction
f = Problems of reintegration

A = Positive reactions (Socio-emotional area: positive)
B = Attempted answers (Task area: neutral)
C = Questions (Task area: neutral)
D = Negative reactions ((Socio-emotional area: negative)
E = Task area neutral

COMMUNICATION TECHNIQUE

The form of communication which allows design collaborators to interact has been called 'Communication Technique'. The technique may be either verbal or visual, and range from technical language to the use of actual objects to convey ideas or issues. The 'Communication Techniques' used in this study are shown in Table 4, and are based on studies conducted by Williams and Cowdroy (2002)

Table 4: Table showing Communication Technique and description

Communication Technique	Description
Verbal Technical Language	The use of verbal language that suggests the user has some knowledge in the area. The use of correct professional jargon.
Non-Verbal Technical Language	The use of non-verbal language that suggests the user has some knowledge in the area. The use of correct professional jargon.
Verbal Non-Technical Language	The use of verbal non-technical language, like that used in greetings.
Non-Verbal Technical Language	The use of non-verbal non-technical language, like that used in greetings.
Verbal Analogy	The use of examples from 1) current project 2) industry projects 3) metaphors from outside the specific industry, to explain a point using verbal language.
Non-Verbal Analogy	The use of examples from 1) current project 2) industry projects 3) metaphors from outside the specific industry, to explain a point using non-verbal language.
Gesture	The use of hand, arm, or finger movements to explain a point.
Graphics – sketching/shading	The creation of graphics by drawing/shading by any method including computer program.
Existing Graphics	The use of graphics already available such as photos or technical drawings
Artefacts	Use of a model or actual object in question during the design process.

RELIABILITY ANALYSIS

To determine the consistency of coding and definition of categories, Intra-Rater reliability was calculated. Two reliability analysis tests conducted through Noldus Observer Pro ethnographic software were based on the frequency of coding strings and also on the frequency and sequence of the coding strings from two observations of the same video data. Video data used was a recording of face-to-face design collaboration using the generic skill coding scheme, Bales's Interaction Process Analysis, and Communication Techniques.

The first reliability test undertaken was a frequency based analysis. This method is based only on the total number of each string of behaviour, so that if one string of code in the first observation occurs *X* number of times, this is compared with the number for that string of code in the second observation.

The second test of reliability is based on the frequency and sequence of the coded data. It attempts to match specific behaviour events by code and time (Burfield *et al.* 2003), between two analysis of the same data.

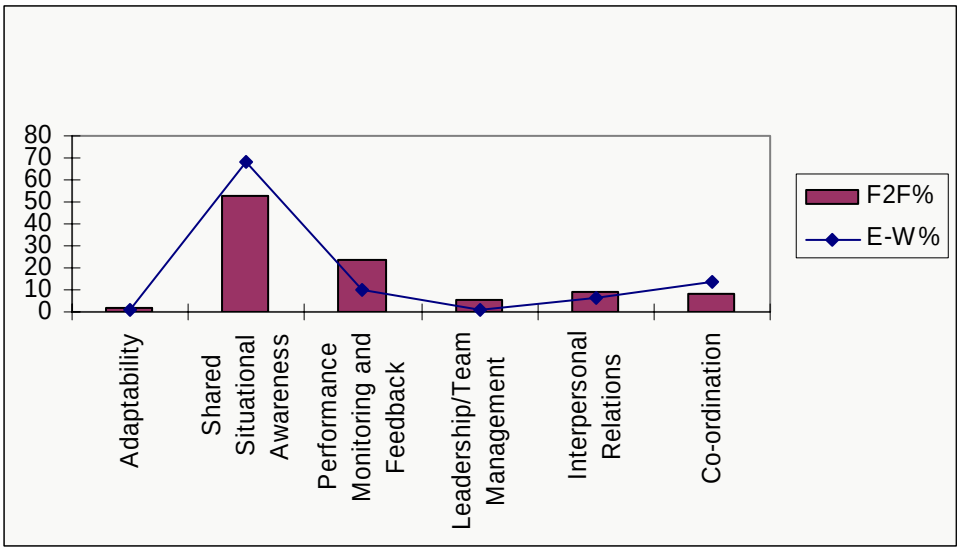
For both tests of reliability, frequency and frequency/sequence, intra-rater reliability of .80 or above was found. This meant that the level of agreement between the two sets of codes for the same video data was 80% or above which is the acceptable level (Kazdin 1982) for reliability testing. It was also found that there was a significant positive correlation between the two data sets, which also indicates reliability for the coding.

RESULTS

The analysis of the videoed sessions provides a preliminary investigation into the study of design teams. The issues which have arisen warrant further research.

Figure 1 compares the face-to-face with the E-Whiteboard conditions on the Generic Skills coding scheme (Table 2). It indicates three areas of difference: - 1) Shared situational awareness, indicating that, 2) Performance monitoring and feedback, indicating a higher percentage use in the face-to-face condition, and 3) Co-ordination where the E-Whiteboard condition shows a higher percentage of engagement in those skills.

Figure 1: Graph indicating the percentages of observations for each category of the Generic Skills Analysis for the Face-to-Face (F2F) and E-Whiteboard (E-W) conditions.

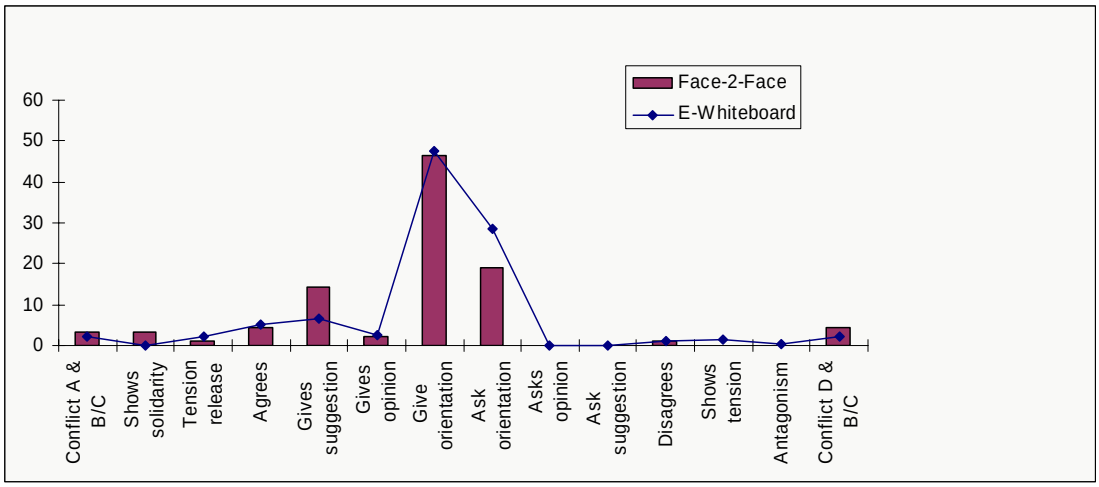


Some hypotheses may be drawn from the literature to explain the differences in the generic skill profiles of co-located and virtual teams. While this is an initial set of results, we offer the following observations:

- 'Shared Situational Awareness': The marked difference between face to face communication (F2F) and electronic whiteboard (EW) may be due to difficulties in sharing an understanding of a design in the virtual world. This is significant in the light of the amount of time designers spend in sharing understanding.
- 'Performance Monitoring and Feedback': This difference may indicate that there is an increased need for this skill in the face-to-face condition or that appropriate levels of feedback are not provided when interacting virtually.
- 'Co-ordination': Co-ordination also encompasses interaction involving technical difficulties, so the increased proportion of this activity for the e-whiteboard condition may be attributed to technical difficulties.

Figure 2 compares the IPA categories in the two stages. As percentages of total interactions, the face-to-face collaborators used proportionally more of the 'Gives Suggestion' category than the E-Whiteboard team. The opposite is true for the 'Asks Orientation' category.

Figure 2: Graph indicating the percentages of interactions for each category of the Bales's IPA for the Face-to-Face and E-Whiteboard operational conditions.

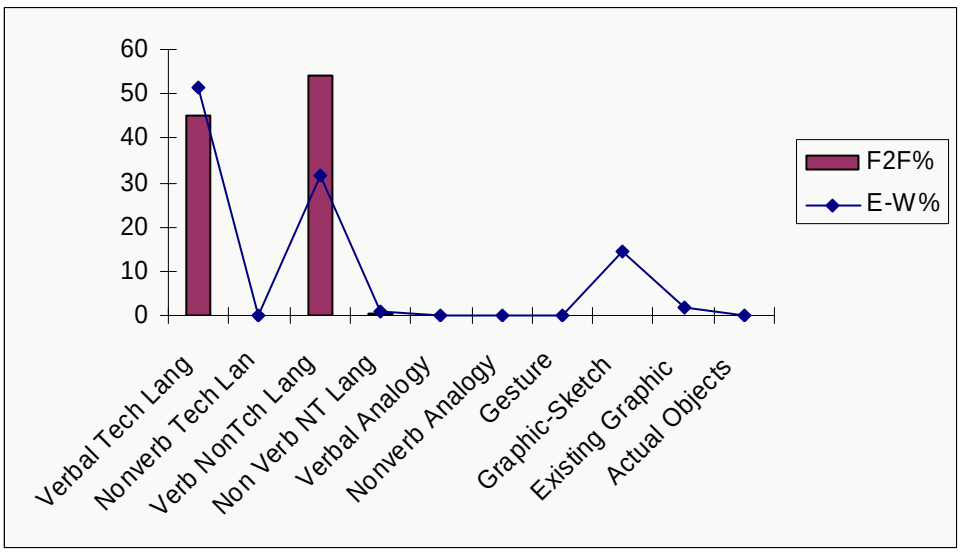


Some conclusions based on literature (Hiltz and Turoff 1982) may be drawn regarding these two areas of difference.

- 'Gives Suggestion': Its increased use in face-to-face collaboration could be a result of the ease of contributing and 'firing off' suggestions and ideas in a co-located 'brain storming' situation compared with EW condition where it is much more involved to spontaneously contribute to team discussion.
- 'Asks Orientation': Its greater use may be due to difficulty in establishing orientation in attempting to share an understanding of the design. This would naturally lead to a higher proportion of questions relating to the design for the E-Whiteboard compared to the face-to-face conditions.

Figure 3 compares the two states and the communication techniques. Although many of the categories of these techniques were not observed, the E-Whiteboard collaborators communicated using two categories (Verbal Technical Language and Graphic Sketches) proportionally more than the face-to-face designers. The opposite was true for the use of Verbal Non-Technical Language.

Figure 3: Graph indicating the percentages of observation for each communication technique category for the Face-to Face (F2F) and E-Whiteboard (E-W) operational conditions.



Some inferences can be drawn from the literature regarding these findings

- Verbal Technical and Verbal Non-Technical Language: The decreased amount of social interaction in the e-whiteboard condition is important as this interaction is a vital ingredient for the development of trust between team members.
- Graphic Sketching: As it is more difficult to pinpoint and describe elements as they appear or should appear on a design using the e-whiteboard, there is a greater need to use the drawing tools in this condition.

CONCLUSION

The ability to map and measure generic skills of individuals and teams is crucial for the construction/design industry. This mapping and measurement can contribute to training in any deficient areas identified not for the technical skills domain, but rather the non-technical. The major deficiency highlighted by literature was the lack of non-verbal capabilities in the virtual world when compared which the co-located condition. This deficiency will lead to different skills and interactions being utilised in the two teams during the analysis.

The intra-rater reliability analysis indicated that the coding scheme formed to conduct this analysis was reliable, while the pilot analysis indicated that the scheme was effective for both operational states. The pilot analysis concludes that there are many factors which are related to the execution of effective design collaboration, both in the face-to-face and virtual world. With further inspection using more data, and closer analysis of those areas identified by these results we will be able to present arguments for differing generic skills profiles between co-located and virtual design collaboration.

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