0271

What it Takes to Design in the Virtual World

Anthony Williams[1], Willy Sher[1], Tom Bellamy[1], Rod Gameson[2]
[1]School of Architecture and the Built Environment, University of Newcastle, Callaghan, Australia,
[2]Faculty of Engeneering and Built Environment, University of Wolverhamton, Wolverhampton,
United Kingdom
tony.williams@newcastle.edu.au

I. INTRODUCTION

Research has indicated that in order to function efficiently and effectively in a team environment, irrespective of whether it is a traditional or virtual team, team members require '*appropriate skills*' (i.e. awareness, understanding, and abilities to apply). One cannot '*assume*' that all team members automatically possess all of the necessary skills for virtual teaming. Previous research has identified that the introduction of new technologies can impact, both positively and negatively, upon the performance of teams. This paper describes the impact the introduction virtual technologies may have on the generic skills of design teams. It examines each of concepts at hand: Design collaboration, virtual teams, and generic skills, using this literature to form a framework for the analysis of design collaboration.

II. DESIGN COLLABORATION

As time and technology move forward, and design projects become more complex, relationships, roles, and responsibilities have become more varied. For these reasons the nature of team work is an important avenue of study before the introduction of ICT's. Teams are a cluster of two or more people usually of differing roles and skill levels who interact '…*adaptively, interdependently, and dynamically towards a common and valued goal.*' (Salas, Burke, & Cannon-Bowers, 2000). They are the vehicle for the process of collaboration (Beyerlein, Freedman, McGee, & Moran, 2003).

Teams which form for a specific project are defined as project teams (Jaafari & Tooher, 2002). These teams are primarily formed quickly and disbanded in the same manner. They are often comprised of members from different backgrounds (i.e. professions) who bring specialised skills to a project. Project teams often have multiple points of authority between the team members, and share '…*decisions, results, and rewards…'* (Cleland & Ireland, 2002). Project teams form the basis of this paper as this research encompasses the early design process, which in the majority of cases, draws designers together for a specific project.

Lawson's research(Lawson, 1997) identified collaboration as a large component of designer's working time. Since this acknowledgement of the profile of collaboration there has been a move toward applying research methods to gain a better appreciation of this activity and the skills required to effectively participate in collaborative design processes. In the process of gaining an understanding of design team activities Muir (Gay & Lentini) defined collaboration as the activity of communication between parties involved on a project, it is an alliance to complete an mission or solve a problem (Kvan, 2000).

Maher et. al. (Kayworth & Leidner) report three different styles of design collaboration, within a collaborative design experiment, as shown in Table I.

Table I . Differing Collaboration Styles (Indicated By Maher (Kayworth & Leidner)

Collaboration Style	**Description**
Constant collaboration	Designers work on the entire design entity while consulting with each other.
Intermittent collaboration	Designers work on different sections of the design, and check with each other intermittently.
Leader controlled collaboration	There is an establishment of a leader who directs the members to specific design tasks.

These types of collaboration all need to be supported in any mode of team, whether co-located, virtual or global virtual.

Professionals involved in team-related activities during the process of design undertake a complex multi-faceted process. The collaborative design process is different from traditional design processes undertaken by individual designers. The difference between individual designers and design teams is encapsulated in the collaboration between participants when creating a new artifact. To begin to appreciate the complexity of this collaborative process requires an understanding of the process. Stempfle and Badke-Schaub (Cleland & Ireland) developed a model, shown in Figure 1, which conveys the characteristics of early project team lifecycle models for design. Like the lifecycle models proposed earlier there appear to be protocol stages, which indicate a consistent process for design teams.

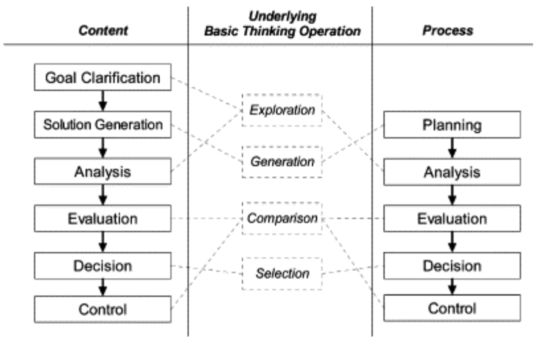

Figure 1. Generic Step Model of Design Team Activities (Stempfle & Badke-Schaub, 2002)

Stempfle and Badke-Schaub's (2002) model, Figure 1, illustrates the steps which define the processes design teams engage in. The content and process steps of the design team are linked via the cognitive processes underlying the actions of exploration, generation, comparison, and selection.

Similarly Thorpe's (Fletcher et al.) 'Generic Design and Construction Process Protocol' classifies the design collaboration process as a method of project management. Thorpe's project management process is based upon four broad stages:

- Pre-project
- Pre-construction
- Construction
- Post construction

To provide a level of detail of the activities which occur within and across these four stages Thorpe (2004) identified the following phases of the process protocol:

- Demonstrating the need (Phase zero)
- Conception of need (Phase one)
- Outline feasibility (Phase two)
- Substantive feasibility study and outline financial authority (Phase three)
- Outline conceptual design (Phase four)
- Full conceptual design (Phase five)
- Coordinate design, procurement, and full financial authority (Phase six)
- Production information (Phase seven)
- Construction (Phase eight)
- Operation and maintenance (Phase nine)

The similarities between the construction process protocol as described by Thorpe (2004) and stages inherent in the design team lifecycle (Figure 1) illustrate that a process protocol could be established solely for design. These models allow us to understand that design and more importantly collaborative design, is a segmented process, punctuated by 4-5 stages that define design processes. From these similarities it is likely that designs process protocols could be those 'process' steps noted by Stempfle and Badke-Schaub (2002) which consist of the stages proposed by Gay and Lentini (Gay & Lentini). To appreciate the diversity of activity which occurs in the team design process requires an understanding of the range of these activities. Gay and Lentini's (1995) study into deign processes in a collaborative virtual environment defined these activities. Their study identified ten specific activities which occurred in a virtual environment, and these are presented in Table II:

The similarities between the 'Generic Design and Construction Process Protocol' (Thorpe, 2004) and ,Stempfle and Badke-Schaub (2002) and Gay and Lentini's (1995), descriptions of design team activity may warrant further investigation to ascertain whether the creation of design team protocol stages is appropriate.

One of the strongest barriers to open and effective collaboration is the professional stereotypes that exist between team members (Gil, Tommelein, Kirkendall, & Ballard, 2001; Muir, 1995). Muir and Gil cite their experience of observing different professions which related certain perceptions of other professions such as the sports car driving architect, and this can lead to serious divides forming between team members when it comes to effective design collaboration.

The activity of collaboration within design teams poses a complex set of variables which require management by a design team manager to gain best outcomes.

Before examining the skills involved with teamwork and how they may be affected by virtual technologies, the composition and nature of teams requires definition. A succinct summary is provided by McDonough et al (Gil et al., , p. 111) who categorises various types of teams, as follows:

- **Co-located teams** are comprised of individuals who work together in the same physical location and are culturally similar.
- **Virtual teams** are comprised of individuals who have a moderate level of physical proximity and are culturally similar. One example of virtual team is where team members are in the same building but on different floors.
- **Global teams** are comprised of individuals who work and live in different countries and are culturally diverse.

Table II . Design Activities Adapted from Gay And Lentini (1995)

Design Activity	**Definition**
Orientating	Establishing contact, familiarization with task and environment. Period in which members establish themselves and become comfortable in the new environment
Subdividing the problem	Defining tasks, objectives, requirements, and boundaries
Establishing roles	Assigning responsibilities, and leadership issues
Information seeking	Researching skills.
Information sharing	Sharing drawings, communicating pictures, gesturing, reporting on research and progress
Monitoring	Clarification of communication channels
Negotiating/ understanding	Explaining design, commenting and questioning, and justification
Designing	Sketching, visualizing, drawing, and manipulating materials
Building	Not relevant to this review of early design
Evaluating	Scrutinising the project in its duration.

III. VIRTUAL TEAMS

Co-location was the principal way that teams operated before technology provided the ability to communicate with others in different physical locations. Co-located teams' interactions are synchronous, occur in a similar place, and their members may be culturally different in terms of different organisations. It is thought that team strength is a result of this social face-to-face (co-located) interaction with team members at work and outside of work (Lurey & Raisinghani, 2001). However, with increasing globalisation of projects it is becoming harder to co-locate these national and global team members (McDonough III, Bahn, & Barczak, 2001).

Virtual teams exist when those members of a team are culturally similar but operate, for the majority of their existence, in different physical spaces such as different cities within the same country (Lurey & Raisinghani, 2001; McDonough III et al., 2001).

As the clients of the construction industry demand more efficient and higher quality services the need to utilise different dimensions and variables on a project increases. Consequently instead of an architect conceptually designing a structure and then seeking approval from a structural engineer, an engineer may be involved from the beginning of a project to advise on pertinent issues (Kayworth & Leidner, 2000). This need for group interaction has led to an increase in partnering between construction organisations from different disciplines (Love, Irani, Cheng, & Li, 2002). Therefore, due to the different geographical locations of project team members, more complex and sophisticated electronic media are being used to communicate ideas and designs (Jaafari & Tooher, 2002).

A. *Comparisons between Co-located and Virtual Teams*

According to Lurey and Raisinghani (2001) there is little difference in the issues that face a co-located team when compared with a virtual team; they are both '...*first and foremost teams*.' (Lurey & Raisinghani, 2001).

Co-located teams are always synchronous, meaning that they meet and exchange information at the same time, while virtual teams can be both synchronous and asynchronous. Where at times they will discuss a project in real time (i.e. via video conferencing and web chat programs) the majority of methods involved email or electronic bulletin boards with a temporal distortion of received material (Maher, Simoff, & Cicognani, 2000). Table III, adapted from (Maher et al., 2000), gives a portrayal of each of the most common forms of team interaction. With the co-located category added, it can be seen that not all virtual methods offer the same array of information, or synchronicity. However, due to time zone differences (i.e. in global teams) the concept of synchronicity is sometimes not relevant to global virtual teams (Kayworth & Leidner, 2000).

B. *Advantages of Working in a Virtual Team*

With the spread of organisations across the globe, and the increase in industrial alliances, virtual teams have become necessary to achieve efficiency, performance, knowledge, stable relationships, and client satisfaction (Gameson & Sher, 2002b). Advantages of virtual teaming include:

- Increase the amount of knowledge and expertise on a project without the need for actual face-to-face meetings.
- Lower travel time and expenditure.
- Members can more effectively organize a shared understanding of the project concepts (forced to work harder to establish a shared mental model (Stempfle & Badke-Schaub, 2002)).
- Able to shorten production life cycle time, because the work can be done in parallel (Lipnack & Stamps, 2000).

C. *Challenges Faced by those in Virtual Teams*

With fast development of and changes in technology in most fields it is not inconceivable that virtual teams may soon exhibit the same generic attributes as co-located teams, such as body language(Gameson & Sher, 2002a). When looking at the skills involved with both co-located and virtual teams it is easy to say that 'technology has all of the answers'; that the same skills seen in a co-located team can be utilised using technology in a virtual team. However, there are other issues to consider, such as:

- Time differences between members.
- Whether the technology is available to all members of the team (Cowdroy & Williams, 2004), and whether they are trained in the use of the technology (Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004).
- Loss of contextual cues, such as body language (Jaafari & Tooher, 2002; Riedlinger, Gallois, McKay, & Pittam, 2004).
- A lack of leadership hierarchy within the remote groups (Jaafari & Tooher, 2002)
- The members are at the mercy of technology. Communication channels could be severed by a fault in the system (Jaafari & Tooher, 2002).
- Different managerial styles between different organisations (Gameson & Sher, 2002a).

Table III

Communication Options for Teams Including Temporal Aspects (Adapted From Maher Et Al 2000).

Type of communication	**Temporal aspect**	**Media**
Email	Asynchronous	Text, Data files
List serves	Asynchronous	Text, Data files
Bulletin boards	Asynchronous	Text, Data files
Talk, chat	Synchronous	Text
Broadcast	Synchronous	Video, Audio
Video conferencing	Synchronous	Video, Audio, Images, Text
Face-to-Face (Co-located)	*Synchronous*	*All*

The move towards a virtual world is becoming ever more relevant in today's unstable world environment. The extent to which a team becomes virtual can be affected by a number of variables including the extent of the distance between members, the number of organisations the members represent, the length of time the team has functioned together (Ratcheva & Vyakaram, 2001), and the experience (i.e. technical skills) of the team members. The extent of a team's virtuality can also be affected by world instability, such as the events of September 11, so that as distance increases, and people are reluctant to leave home due to international issues, the degree of a team's virtuality increases (Kirkman, Rosen, Gibson, Tesluk, & McPherson, 2002).

Whilst there are some challenges faced by those working in virtual teams, the benefits seem to be a selling point. In the long run virtual teams are less expensive and more time efficient, as well as increasing the amount of knowledge and skills within these teams.

IV. GENERIC SKILLS

In Human Factors research conducted by Salas et al into teams, generic skills have been defined as those that influence both individuals and teams (Salas et al., 2000). They are skills which are *'…transportable and applicable across teams'* (Salas et al., 2000).

Human Factors research is based in understanding the human side of organisational and team operation, the non-technical or generic aspects. This area has amassed a large amount or literature regarding generic skills within teams, as has research into successful computer mediated communication. The list below describes those generic skills which, have been suggested, significantly contribute to successful collaborative activities:

- Adaptability
- Shared Situational Awareness
- Performance Monitoring and Feedback
- Leadership/Team Management
- Interpersonal Relations
- Co-ordination
- Communication
- Decision Making

These generic skills, cited within literature, create a basis for the creation of a behavioural markers scheme used to measure these skills during design collaboration(Bellamy, Williams, Sher, Sherratt, & Gameson, 2005).

V. METHOD

A. *Experimental Design Sessions*

In order to meet the aims and objectives of this study, those individuals participating in collaborative design teams needed to be identified. They needed to be involved in the design industry at some level whether architectural, engineering, construction or other similar professions. In order to assess these designer's and design team's generic skill profile it was agreed that video and audio data of actual design collaboration would yield the most informed results.

Participants were randomly chosen from design staff of Australian architecture firms who had agreed to participate. Participants chosen could be of either gender and had a varying degree of experience and influence (power), with the range being from higher management to junior staff. Also present were age differences. It was unknown what training in terms of tertiary or TAFE education the participants had engaged in, and whether they had any training in the area of collaborative design teams or collaborative technologies. This random assignment suited the study as it was representative of the way design teams can occur in actual design processes. It is often the case that those design team members are from very different backgrounds/cultures, ages, and experience (Marchman, 1998), especially in multi-disciplinary design teams collaborating on an entire project.

Video data of participants collaborating in two person design teams was collected for three differing levels of virtual technology. This allowed observation of any differences in generic skills used between the three conditions. The three experimental conditions are described below:

- Traditional Collaborative Design (face-to-face) – This included simple face-to-face interactions such as talking and sketching.
- Shared Electronic Whiteboard - Facilitated shared drawing, images and text. Also included were synchronous speech and visual communication via a web camera.
- High Bandwidth Multi-user 3D Virtual Worlds - Team members manipulate a 3D representation of a design using computer based tools, communicating through 'chat', video and synchronous speech facilities.

Before each design session the research team spent 1-2 hours coaching designers in the capabilities of the above technologies. Once designers were suitably familiar with the software, they were permitted to participate in the design sessions.

Each designer was given a brief which related to the architectural aspects and their expected role in the design process. These briefs related to fictional projects on an actual site at Sydney University. Depending on the session, briefs asked designers to design an art gallery, a hostel, a library or a dance school for the site. The collaborators were then given 30 minutes to design the structure as their profession required for each session interacting using one of the three collaboration types.

B. *Analysis Framework*

Human Factors research was analysed in order to create a framework for the analysis of the video and audio data of design team collaboration. The methods described by behavioural marker studies have been used as a template for the Generic Skills framework.

Behavioural markers are observable non-technical (Klampfer et al., 2001) *'…aspects of individual and team performance'* (Carthey, de Leval, Wright, Farewell, & Reason, 2003, p. 411) which are related to the effectiveness of an individual and team. Behavioural markers, or more specifically the methods for the creation of behavioural markers(Bellamy, Williams, Sher, Gameson, & Sherratt), are being analysed because they offer a physical description of non-technical skills Kjellberg, Haglund, Forsyth, & Kielhofner, 2003). Klampfer et al (2001) enforce the need for simple and clear behavioural markers, which use appropriate jargon and terminology. Emphasis should be placed on an observable behaviour rather than an ambiguous attitude or opinion.

The Anaesthetists' Non-Technical Skills (ANTS) (Fletcher et al., 2004) system has been changed and adapted for use with design teams (full framework shown Appendix 1). The nature of generic or non-technical skills implies that they are transportable between teams, as they are not directly involved in the technical aspects of the process. Using the ANTS system in the design domain allowed us to merge some of the skills previously mentioned, and create a simple coding scheme which incorporates those skills listed in Section IV (Table IV).

Table IV . Relationship Between the Ants Generic Skills, and Salas's (2000) Generic

ANTS Generic Skills (Fletcher et al., 2004)	**Literature Generic Skills (Salas et al., 2000)**
Task Management	Leadership/Team Management Performance Monitoring and Feedback
Team Working	Interpersonal Relations Co-ordination
Situational Awareness	Adaptability
Decision Making	Decision Making

Communication has not been included because, while it appears to be an essential component of team interaction, it is impossible to separate it from the observable behaviours associated with skills. Behavioural marker research indicates, communication is such an essential part of these non-technical skills that the nature of the analysis dictates that communication is not able to be separated from these skills (Fletcher et al., 2004). In this way communication need no longer be part of the generic skills coding scheme as it is inherent in every other skill.

Once the video data had been coded using the analysis framework described in Appendix 1, the frequencies for each observable behaviour could be determined. This would indicate generic skill frequencies for each operational condition, thus allowing differences between generic skills profiles to be analysed. Analysis was achieved using Chi square tests to determine whether there were significant differences between the generic skills profiles of the different operational conditions: Face-to-face, electronic whiteboard, and 3D virtual world.

VI. RESULTS

The Generic Skills Analysis Framework was used to code the design collaboration videos for two design teams. The coded data was then analysed for the two teams separately and then as combined design activity to test both individual team and overall design results.

Analysis of Generic Skills for Team 1 Design Activity

Analysis of the face-to-face and virtual design interactions for Team 1 using the Generic Skills coding scheme (Figure 10.1.1) indicates that there are large differences in all four skill areas. These differences are between the skills profiles seen for the three experimental conditions; face-to-face, group board, and 3D virtual world. These overall differences are supported by a Chi square test to determine the 'goodness of fit' for the operational conditions $\chi^2(6, N = 819) = 58.64$, $p = .000$. These differences are supported by the 'adjusted standardised residuals' (ASR) recorded in Table 10.1.1. Values here which are greater then ± 2 indicate a driver of overall significant difference. As can be seen, this includes all points relating to face-to-face and 3D virtual world conditions except for *team working* in the 3D virtual world condition.

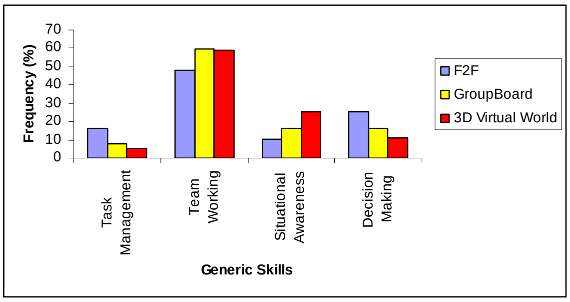

Figure 2 Graph indicating the percentages of observations for each category of the Generic Skills Analysis for the face-to-face, group board, and virtual world for Team 1.

The results of the chi square analysis and the graph of generic skills frequency for Team 1 indicate that:
There is a significant and consistent decrease in frequency of *task management* and *decision making* generic skills as designers moved from low to high bandwidth.

There is a significant and consistent increase in frequency of *situational awareness* generic skills as designers moved from low to high bandwidth.

There is a significant difference between the frequency of *team working* generic skills in the face-to-face condition when compared with the frequency of *team working* generic skills in the group board and 3D virtual world conditions.

Analysis of Generic Skills for Team 2 Design Activity

Significant differences were also found for the generic skills profile of Team 2 $\chi^2(6, N = 1191) = 31.44$, $p = .000$ (Figure 10.1.2). As was found in Team 1, the drivers of this significance, according to the adjusted standardised residuals in Table 10.1.2, are not related to the group board condition. The drivers for Team 2 appear to be once again related to the face-to-face and 3D virtual world conditions, most significantly for *team working*, *situational awareness* and *decision making*.

The results of the chi square analysis and the graph of generic skills frequency for Team 2 indicate that:
There is a significant and consistent decrease in the frequency of *decision making* as designers moved from low to high bandwidth conditions.

There is a significant and consistent increase in the frequency of *situational awareness* as designers moved from low to high bandwidth conditions.

The frequency of *team working* in the 3D virtual world is significantly different to that of the frequency of *team working* in the face-to-face and group board condition.

Analysis of Generic Skills for Total Design Activity

To provide an overview of these results the two team's design activity was combined to establish if there was an overall significance for generic skills of total design activity analysed. The chi square analysis of total design activity indicated that this was also significant $\chi^2(6, N = 2010) = 65.89$, $p = .000$ with similar percentages seen in Teams 1 and 2 (Figure 10.1.3). Once again, according to the ASR table (Table 10.1.3), the significance was not driven by the group board condition but the face-to-face and 3D virtual world conditions. For the generic skills analysis it appears that there is a consistent increase or decrease in each of the skills as the participants moved from face-to-face to group board to the 3D virtual world condition. Both the task management and decision making skills decreased as virtuality increases, while the opposite is true for team working and situational awareness.

The results of the chi square analysis and the graph of generic skills frequency for, total design team activity, indicate that:

There is a significant and consistent increase in the frequency of *team working* and *situational awareness* as team members moved from low to high bandwidth conditions.

The is a significant and consistent decrease in the frequency of *decision making* as team members moved from low to high bandwidth conditions.

Table V . Table of Adjusted Standardised Residuals for Team 1 Generic Skills, Which Indicates Drivers of Overall Significance.

	Task Mngt	Team Working	Situational Awareness	Decision Making
ASR F2F	**4.6**	**-3.1**	**-3.7**	**4.2**
ASR GB	-1.2	1.6	-0.6	-0.6
ASR 3D Virtual World	**-3.4**	1.6	**4.3**	**-3.7**

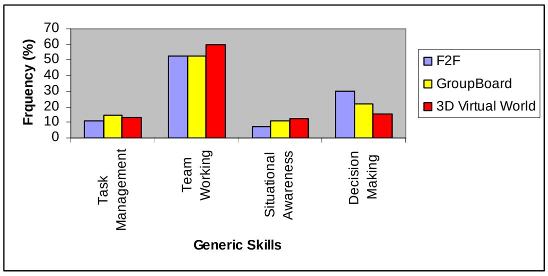

Figure 3 Graph indicating the percentages of observations for each category of the Generic Skills Analysis for the face-to-face, group board, and virtual world for Team 2.

Table VI . Table of Adjusted Standardised Residuals for Team 2 generic skills, which indicates drivers of overall significance.

	Task Mngt	Team Working	Situational Awareness	Decision Making
ASR F2F	-1.45	-1.3	**-2.6**	**4.6**
ASR GB	1.3	-1.1	0.6	-0.2
ASR 3D Virtual World	0.2	**2.3**	**2.0**	**-4.4**

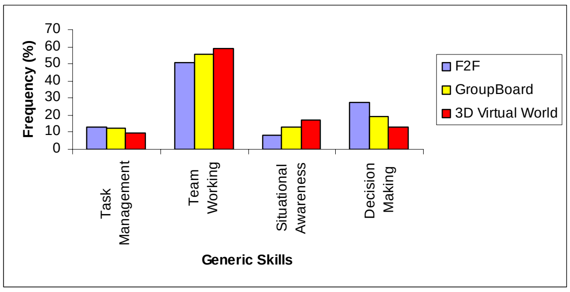

Figure 4 Graph indicating the percentages of observations for each category of the Generic Skills Analysis for the face-to-face, group board, and virtual world for Total generic skill usage of Team 1 and 2 combined.

Table VII . Table of Adjusted Standardised Residuals for Total of Team 1 and 2 generic skills combined, which indicates drivers of overall significance.

	Task Mngt	Team Working	Situational Awareness	Decision Making
ASR F2F	1.5	**-3.0**	**-4.4**	**6.1**
ASR GroupBoard	0.3	0.2	0.03	-0.5
ASR 3D Virtual World	-1.8	**2.8**	**4.4**	**-5.7**

Table VIII . Generic Skills Coding Scheme

Non-Technical Skill	**Observable Behaviour**	**Example**
Task Management	Planning or preparing a task	• Outlines and describes the plan/brief for the design • Reviewing the design after changes are made • Describes what actions are to take place once the design is completed
	Prioritising tasks	• Assigns priority to design tasks to be completed • Prioritises the segments within design tasks
	Providing direction and maintaining standards for the task	• Follow design protocols and briefs • Cross checks the completion of design tasks
	Identifying and utilising resources	• Identifies and allocates resources • Allocates tasks to team members • Requests additional resources
Team Working	Co-ordinating activities with team members	• Confirms roles and responsibilities of team members • Considers requirements of others before acting • Co-operates with others to achieve goals
	Exchanging information	• Gives updates and reports key events • Confirms shared understanding • Communicates design plans and relevant information to relevant members • Clearly documents design

	Using authority and assertiveness	• Is appropriately and necessarily assertive • Gives clear orders • States case for order and gives justification
	Assessing capabilities	• Asks for assistance • Asks team member about experience • Notices that a team member does not complete task to appropriate standard
	Supporting others	• Acknowledges concerns of others • Reassures/Encourages • Debriefs • Anticipates when other will need information or designs
Situational Awareness	Gathering information	• Asks for documents and/or information regarding an idea or design • Checks on status of project and tasks • Collects information regarding a 'problem' • Cross checks and double checks information
	Recognising and understanding	• Describes seriousness or urgency of task (deadlines) • Pays closer attention on advice of fellow team member
	Anticipating	• Takes action to avoid future problems • Reviews effects of a change
Decision Making	Identifying options	• Discusses design options with clients/other designers • Discusses various techniques for the design
	Balancing risks and selecting options	• Weighs up risks associated with different design options • Implements chosen design
	Re-evaluating	• Re-evaluates chosen design technique after it has been chosen

VII. DISCUSSION

Overall the results from the analysis of the collaborative design indicate that the method of collaboration does appear to have an impact on the frequency of generic skills and interactions. Team 1 and Team 2 had similar results in terms of the profiles, for both generic skills (Tables V - VII).

There was a significant and consistent increase in the frequency of the ***team working*** generic skill as the design collaborators moved from face-to-face to group board to 3D virtual world. This increase indicates that designers have employed this generic skill increasingly as virtuality has increased. ***Team working*** observable behaviours which were commonly seen during the coding of the video data were 'confirming shared understanding', 'communication design plans' and 'reassuring and encouraging'.

- Confirming shared understanding involves asking for confirmation on something another designer has drawn, said or written. It is a question for which the 'enquirer' may already know or have access to the answer. A rise in this behaviour indicates an increased need for checking and accuracy, also a lack of confidence in making decision with apparent data must be considered.
- Communicating design plans involves one designer describing what they can see on the design plans i.e. drawings. This includes details such as lengths and area. An increase in this activity indicates a greater need for co-ordination and shared understanding. So as the designers are less able to communicate using non-verbal cues they become more reliant on the ability to describe (verbally) the area to which they attending.
- Reassuring and encouraging involves one participant praising or agreeing with another's idea or point of view in a positive manner. An increase in this behaviour may indicate that there is a need for greater positive reinforcement in the virtual conditions. So as virtuality increases and becomes less familiar there is a greater need to support each other in actions and ideas as they use the unfamiliar technology.

There was a significant and consistent increase in the frequency of ***situational awareness*** generic skills application as designers moved from low to high bandwidth. The overriding behaviour which was scored for this generic skill was 'gathering information'. Gathering information involves one designer asking another a question regarding the design, the site, an idea or even artifacts. An increase in the frequency of this behaviour indicates simply an increase in the amount of questions asked by the designers of each other, which may indicate escalating levels of uncertainty.

There was a significant and consistent decrease in the frequency of ***decision making*** generic skill usage as designers moved from low to high bandwidth. The observable behaviour which was scored most frequently for this generic skill was 'discusses design options'. Discusses design options involved one designer suggesting an idea for a design to another. Therefore a decrease in this activity would indicate that the designer spent a significantly less amount of time suggesting possible solutions to the design problem as they moved from low to high bandwidth conditions.

The findings of this study provide a clearer understanding of the implications for working collaboratively in the team context in the virtual design context. Cognizance of the skills and strategies to improve performance of designers will in turn improve the performance of teams as they participate in the virtual design team.

References

Bellamy, T., Williams, A., Sher, W., Gameson, R., & Sherratt, S. (2005). *Generic skills in design teams: Data analysis* (Technical No. 2002-024-3-03-2004). Newcastle, Australia: The University of Newcastle.

Bellamy, T., Williams, A., Sher, W., Sherratt, S., & Gameson, R. (2005, 7-9 September 2005). *Design communication: Issues confronting both co-located and virtual teams.* Paper presented at the Association of Researchers in Construction Management 2005, London, England.

Beyerlein, M., Freedman, S., McGee, C., & Moran, L. (2003). *Beyond teams: Building the collaborative organization.* San Francisco: Jossey-Bass/Pfeiffer.

Carthey, J., de Leval, M., Wright, D., Farewell, V., & Reason, J. (2003). Behavioural markers of surgical excellence. *Safety Science, 41*(5), 409-425.

Cleland, D., & Ireland, L. (2002). *Project management: Strategic design and implementation 4th edition.* New York: McGraw-Hill.

Cowdroy, R., & Williams, A. (2004, April). *Profiling Designers as a Basis for Design Performance.* Paper presented at the Design 2004, Dubrovnik.

Fletcher, G., Flin, R., McGeorge, P., Glavin, R., Maran, N., & Patey, R. (2004). Rating non-technical skills: Developing a behavioural marker system for use in anaesthesia. *Cognition, Technology, and Work, 6*(3), 165-171.

Gameson, R., & Sher, W. (2002a). *An investigation into perceptions of project team dynamics and the utilisation of virtual environments.* Paper presented at the Proceedings of the eighteenth annual conference, Association of Researchers in Construction Management (ARCOM), Northumbria University, UK.

Gameson, R., & Sher, W. (2002b). *Project team intergration: Communication, coordination and decision (interim report).* Newcastle: The University of Newcaste.

Gay, G., & Lentini, M. (1995). Use of communication resources in a networked collaborative design environment. *Journal of Computer Mediated Communication, 1*(1), 1-6.

Gil, N., Tommelein, D., Kirkendall, R., & Ballard, G. (2001). Leveraging specialty-contractor knowledge in design-build organisations. *Engineering Construction and Architectual Management, 8*(5-6), 355.

Jaafari, A., & Tooher, T. (2002, June 2-7, 2002). *Building virtual teams for success: A learning an development framework.* Paper presented at the The 16th IPMA World Congress on Project Management, Berlin, Germany.

Kayworth, T., & Leidner, D. (2000). "The global virtual manager: A perscription for success". *European Management Journal, 18*(2), 183-194.

Kirkman, B., Rosen, B., Gibson, C., Tesluk, P., & McPherson, S. (2002). Five challenges to virtual team success: Lessons from Sabre, Inc. *Academy of Management Executive, 16*(3), 67-79.

Kjellberg, A., Haglund, L., Forsyth, K., & Kielhofner, G. (2003). The measurement of properties of the Swedish version of the assessment of communication and interaction skills. *Scandinavian Journal of Caring Science, 17*(1), 271-277.

Klampfer, B., Flin, R., Helmreich, R., Hausler, R., Sexton, B., Fletcher, G., et al. (2001). *Enhancing performance in high risk environments: Recomendations for the use of behavioural markers.* Paper presented at the Behavioural Markers Workshop, Zurich, Switzerland.

Kvan, T. (2000). Collaborative design: What is it? *Automation in Construction, 9*, 409-415.

Lahti, H., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2004). Collaborative patterns in computer supported collaborative designing. *Design Studies, Article in press: Available online 27 February 2004*.

Lawson, B. (1997). *How designers think: the design process demystified* (Vol. 1990). Oxford: Architectual Press.

Lipnack, J., & Stamps, J. (2000). *Virtual teams: People working across boundaries with technology.* New York: John Wiley & Sons.

Love, P., Irani, Z., Cheng, E., & Li, H. (2002). A model for supporting inter-organisational relations in the supply chain. *Engineering, Construction, and Architectual Management, 9*(1), 2-15.

Lurey, J., & Raisinghani, M. (2001). An empirical study of best practices in virtual teams. *Information & Management, 38*(8), 523-544.

Maher, M., Simoff, S., & Cicognani, A. (2000). *Understanding virtual design studios.* London: Springer.

Marchman, J. (1998). Multinational, multidisciplinary, vertically integrated team experience in aircraft design. *International Journal of Engineering Education, 14*(5), 328-334.

McDonough III, E., Bahn, K., & Barczak, G. (2001). An investigation of the use of global, virtual, and colocated new product development teams. *The Journal of Product Innovation Management, 18*, 110-120.

Muir, T. (1995). Introduction to collaborative practice. In T. Muir & B. Rance (Eds.), *Collaborative practice in the built environment* (pp. 15). London: E & FN SPON.

Ratcheva, V., & Vyakaram, S. (2001). Exploring team formation processes in virtual partnerships. *Integrated Manufacturing Systems, 12*(7), 512-523.

Riedlinger, M., Gallois, C., McKay, S., & Pittam, J. (2004). Impact of Social Group Processes and functional diversity on communication in networked organisations. *Journal of Applied Communication Research, 32*(1), 55-79.

Salas, E., Burke, C., & Cannon-Bowers, J. (2000). Teamwork: Emerging principles. *International Journal of Management Reviews, 2*(4), 339-356.

Stempfle, J., & Badke-Schaub, P. (2002). Thinking in design teams-an analysis of team communication. *Design Studies, 23*(5), 473-496.

Thorpe, T. (2004). *Process issues in construction.* Retrieved 10.06. 2004, 2004, from http://hkusury2.hku.hk/CIT/1