Contributing to the Virtual Design Team: Considerations and Requirements

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Abstract: In the modern world, design activity is not alone in feeling pressure from limited resources, rising costs, and competition. Factors including increase of global competition and collaboration as well as the affordability of Information and Communication Technology (ICT) are promoting the role of virtual design teams in preference to traditional co-located design teams.

The operational differences which result from using different electronic communication media and its impact on generic design skills have been the basis for the research reported in this paper. The outcome of this research is the development and mapping of generic skills profiles for virtual design teams and the designers who work in them. The research findings also identify changes in generic skills profiles between the traditional mode of team design as well as the different operational states of current and future ICT environments.

This paper examines design team activities, processes and skills occurring in co-located environments and links these with those of virtual teams. This is achieved by documenting the results of analyses of video data of designers involved in collaborative design using various ICT technologies, ranging from traditional co-located systems to high bandwidth 3D virtual worlds. The analyses identify that ‘appropriate generic skills’ are necessary when interacting and collaborating using different electronic media and this study presents a case for ongoing research into the area of generic skills within virtual design teams.

Key words: Design Management, Design Education, Virtual Design

1. Introduction

1.1 Teamwork: A dynamic paradigm

There is increasing practical and theoretical interest in how design teams can manage, organize, and integrate knowledge in the process of collaborative design. Because the diversity of knowledge workers, including designers, is increasing [1] and knowledge is fundamental to the functioning of design teams, the successful pursuit of design activities creates competitive advantages; in particular in analysing product development. In manufacturing firms, industry observers suggest that managing knowledge through the use of concurrent engineering and multi-disciplinary design teams accelerates the time it takes to get a product to its market, technology transfer and innovation [2, 3].

While design research has identified the importance of cross-functional integration [4-6], scholars and practitioners also recognise that integrating such a diversity of professional personalities is problematic. Wheelwright and Clark [5] suggest that different functional groups should be actively involved in the phases of development. This is important to optimise the timing, frequency, direction, and medium of communication which impacts on the success of this integration. However, even in instances where communication is successful, creating shared understandings may still be problematic [7]. Individuals working in Design Teams, due to the specialisation inherent in performing their own tasks successfully, have different perspectives on their work and organisations [8-10]. They also develop local knowledge as a consequence of differences in expertise and experience [11]. The differences in knowledge and perspectives between teams and team members can result in difficulties sharing information in a constructive way. Design management needs to capitalise on coordinating the functions which challenge shared understandings of the different design professions involved.

Research has identified that challenges exist in the optimisation of processes used by organisations to codify and transfer knowledge across boundaries. This work suggests that organisations use structures and processes such as routines and standard operating procedures to codify and transfer knowledge from localised contexts [12, 13].

Within virtual design team environments there has been a compounding of the issues associated with the management of design teams. This has promoted the development of shared understandings among the designers within the context of the global spread of organisations, and the increase in industrial alliances. Virtual teams have become necessary to achieve efficiency, performance, knowledge, stable relationships, and client satisfaction [16]. Organisations are able to increase the amount of knowledge and expertise they bring to a project without designers having to meet face-to-face, lowering travel time and expenditure. Initially disadvantages may be seen when members of a virtual team do not have a shared understanding (i.e. a mental model) of the concepts of the project in question. Without this shared understanding they must form their own understandings. This is done through questioning and in most cases this method of establishing a shared mental model will highlight areas of weakness or error [17]. For this reason teams from different "cultures" often outperform those with homogeneous "cultures" because those members from different cultures need to work significantly harder to establish shared mental models [17]. Virtual teams are also often able to shorten the production life cycle time because work can be done in parallel instead of in a stereotypical production line (or serial mode) [18].

1.2 ICT in the Design Industry

According to Lurey and Raisinghani [19] 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.*' [19 p, 532]

Co-located teams always operate synchronously, meaning they meet and exchange information at the same time, while virtual teams can be both synchronous and asynchronous. At times virtual discussion will be in real time (i.e. via video conferencing and web chat programs) but the majority of methods involve email or electronic bulletin boards with a temporal distortion of received material [20]. Table 1, adapted from [20], portrays each of the most common forms of team interaction. It can be seen that not all methods offer the same array of information, or synchronicity. However, due to time zone differences synchronicity is sometimes not relevant to global virtual teams [21].

Table 1. Communication options for teams including temporal aspects (adapted from Maher et al [20]).

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 conference	Synchronous	Video, Audio, Images, Text
Co-located	Synchronous	All

1.3 Generic Skills required for Design Collaboration

Generic skills are defined as the knowledge, skills and attitudes that a team member possesses and can commit to completing a task or communicating with fellow members [22]. To this end skills development and training should be viewed by management as an investment in creating more valuable and skilled employees. Providing team members with the skills needed to contribute to virtual environments is a long but necessary process [23] if errors associated with miscommunication are to be avoided.

In Salas' research involving teams, generic skills have been defined as those that influence both individuals and teams [22]. They are skills which are *'...transportable and applicable across teams'* [22 p, 344]. In this study the following skills were considered:

- Adaptability
- Shared situational awareness
- Performance monitoring and feedback
- Leadership/team management
- Interpersonal relations
- Co-ordination

Definitions are provided in Appendix A.

2. Method

This paper describes the use of video recordings of design collaboration to test whether there are significant differences between the generic skills profiles of those engaging in co-located design (face-to-face) and those design teams interacting using virtual or ICT means.

2.1 Participants

The participants were involved in architectural or engineering design. As participation in the investigation was restricted to research partners of the Co-operative Research Centre for Construction Innovation [CRC-CI], a project architectural firm was used as a source of participants. This firm was multi-national with offices in Sydney and Melbourne, and multiple offices in Asia and Europe as well as other Australian capital cities.

The participants were randomly chosen from design staff based on their relative availability. They were of a diversity of gender, age and degree of experience and influence (power), representing higher management to junior staff [24]. In total five participants agreed to take part in the study. Three were videoed participating in co-located activities and two in virtual activities.

2.2 Materials

Digital video recording was used as the method of data collection. . The advantages of video recording participants include: the ability to review interactions and behaviours, as well as the ability to compare different coders or viewers' interpretations. In addition video recordings can become a replacement for live observation [25].

The physical technical setup included:

- **Cameras,** two of which were used during the co-located stage to monitor actual design activity and the designers. Only one camera was used in the virtual stage because direct streaming (and recording) was used to record the design activity from the computer/whiteboard.
- **A removable hard-disk** which allowed easy transport and maneuvering between research locations.
- **Tie-clasp microphones** which were used to record audio in an unobtrusive manner.

2.3 Procedure

Participants used two differing levels of bandwidth (co-located and virtual levels) or operational modes so that differences in the generic skills used between these could be observed**.** These two levels are:

- **Traditional collaborative design:** using the communication and design tools currently being employed by those co-located design team members. These included simple face-to-face (F2F) interactions such as talking and sketching.
- **Virtual collaborative design:** using a shared electronic whiteboard which allowed users at remote locations to view shared drawings, images and text synchronously. Also included were synchronous speech and visual communication which was facilitated using a web camera.

While co-located participants were familiar with their surroundings and the techniques involved in the collaborative design sessions, the virtual participants needed to be trained and familiarised with the functions and use of their new collaborative computer software. Before each design session the research team spent approximately half an hour familiarising participants with the technology.

Once participants were familiar with the software, they took part in the design sessions. No briefing on the architectural project was provided and each participant was asked to discuss and share the architectural aspects of a design they were working on with the other participant also working on the same project. The two sessions were each approximately 30 minutes in length.

Once the design sessions had been videoed they were formatted into MPEG-4 files and the data was coded using ethnographic software Noldus Observer Pro. This application is a '…manual event recorder for the collection, management, analysis and presentation of observational data' [26 p, 21]. It allows researchers to view live or recorded video data, and score the frequency of specific behaviours, as well as how these behaviours interact with each other or with independent variables. The coding of the traditional and virtual design team data was based on those generic skills described above (and detailed in Appendix A), and consisted of a list of observable behaviours (listed in Appendix B). For each session (F2F and virtual), the coder recorded the participant and the observable behaviour (generic skill).

2.3.1 Testing the Research Method

Intra-rater reliability was used to confirm that the coding was consistent and that codes were clearly defined. Two reliability analysis tests were conducted through Noldus Observer Pro on the 'behavioural records'. These were each recorded interaction which included the time, participant, and generic skill utilised:

- Frequency Based: which tested whether the total number for each possible combination of behavioural record was the same in both sets of codes for the same video data, and
- Frequency/Sequence Based: which tested not only the frequency (above), but also whether the timing of specific behavioural records, as assessed by the raters, matched, as in, behavioural record 1 (first coding session) is the same as behavioural record 1 (second coding session), and they occur at approximately the same time.

The reliability analysis went through several iterations before a final coding scheme met appropriate criteria for intra-rater reliability. Only those results for the final coding scheme are presented. The final coding scheme's reliability was tested on a face-to-face design session. The frequency based reliability analysis revealed a large percentage of agreements at 80%. This high percentage of agreement between the coding sessions implies that the coding scheme had reached a satisfactory level for intra-rater reliability. Pearson's rho (0.98) indicates that there is a high level of positive correlation between the two sets of observations, and the t-test shows that this reached a significant level $t(-2) = 46.67$, $p < .001$. A similarly higher rate of agreements (84%) was found for the frequency/sequence analysis (Pearson's rho 0.96; $t(-2) = 32$, $p < .001$).

For both tests of reliability, frequency and frequency/sequence, intra-rater reliability of .80 or above was found, indicating an acceptable level of agreement [27]. The significant positive correlation between the two data sets also indicates reliability for the coding scheme.

3. Results and Discussions

The analysis of the videoed design sessions using the generic skills coding scheme provides information for the further investigation of generic skills within collaborative design teams. Results, presented below, will allow conclusions to be drawn as to how generic skills profiles may differ between the two operational states, and provide an insight into further research to be conducted.

Chi square analysis was conducted to determine whether there is a '…good fit' [28] between the data one would expect for design collaboration (co-located) and data for the virtual design tem collaboration. The Monte Carlo exact test was used as there were variables which had a cell count less than five. In Table 2 it can be seen that the Monte Carlo Chi squared test indicates significance $\chi^2(5, N = 370) = 25.828$, $p = .000$ showing a difference exists between the skills profile of those collaborating in a co-located environment when compared with a virtual environment.

Table 2 Results of Chi Square test, displaying results for Monte Carlo exact test.

	Value	df	Asymp. Sig. (2-sided)	Monte Carlo Sig. (2-sided)
Pearson Chi-Square	25.828(a)	5	.000	.000
Likelihood Ratio	27.264	5	.000	.000
Fisher's Exact Test	25.990			.000
N of Valid Cases	370			

a. 2 cells (16.7%) have expected count less than 5. The minimum expected count is 1.91.

Analysis of the skill profiles for the co-located and virtual design interactions for the Generic Skills coding scheme (Figure 1) indicates there were four large areas of difference: - 1) Shared situational awareness, 2) Performance monitoring and feedback 3) Leadership/team management and 4) Co-ordination. For both the shared situational awareness and the co-ordination generic skills the virtual team has a higher percentage than in the co-located condition, while the opposite is true for performance monitoring and feedback and leadership/team management.

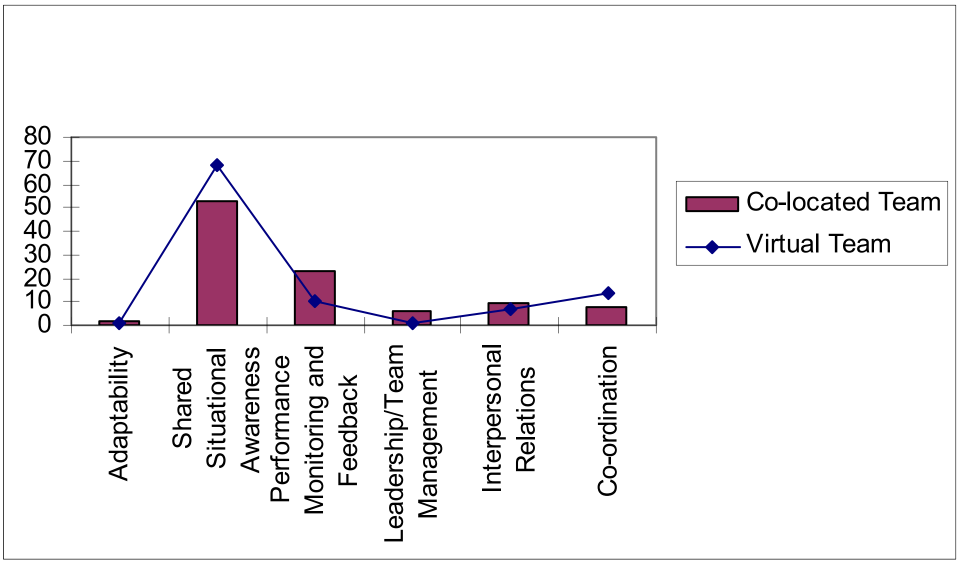

Figure 1. Graph indicating the percentages of observations for each category of the Generic Skills Analysis for the co-located and virtual conditions.

The differences seen in Figure 1 between the operational states assist in forming hypotheses about what may be seen when further data is collected.

- Shared Situational Awareness: The differences between co-located and virtual interaction may reflect the difficulties in sharing an understanding of a design in the virtual world. As designers spend a significant amount of time engaged in sharing their understanding of a design, this difference is important and could affect the course of design collaboration. It may be that virtual collaboration is not an environment conducive to sharing understanding because of difficulties in combining an array of communication techniques in this condition.
- Performance Monitoring and Feedback: This difference may indicate that there is an increased need for this skill in the co-located condition or that appropriate levels of feedback are not provided when interacting virtually. It may be difficult to give feedback in a virtual environment due to the one sided nature of communication, with the possibility of one team member dominating interactions. ????
- Leadership/Team Management: The differences seen between co-located and virtual design collaboration on this skill follows the ideas expressed by Gameson and Sher [16]. ??? They report that there would be difficultly maintaining a managerial style when moving from a co-located to a virtual environment.???
- Co-ordination: According to the coding scheme, 'Co-ordination' also included those interactions which related to technical difficulties. A higher level of co-ordination communication could indicate that there was an increase in technical difficulties in the virtual condition.

4. Conclusions

The ability to map and measure generic skills of individuals and teams is crucial for the construction/design industry. Any deficiencies in non-technical skills can be identified and targeted for training. This may lead to different skills and interactions being utilised in virtual teams than in traditional co-located teams.

Previous research has identified that the introduction of new technologies can impact, both positively and negatively, upon the performance of teams. When the coding scheme was applied to the two operational design team states significant differences between the skills profiles were identified. These differences give an indication of how virtual team operation can differ from the commonly used co-located environment. With the collection of more data and closer analysis of the areas identified by these results, support may be provided for differing generic skills profiles in co-located and virtual design collaboration. This in turn will encourage more virtual interactions, and facilitate the smooth running of virtual teams. Early identification of skills and skills profiles will allow strategies to be used to facilitate interaction in virtual design collaboration.

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Appendix A

Table A. Table of Generic Skills for Team Collaboration

Generic Skill	Description
Adaptability	The use of compensatory behaviour and reallocation of resources to adjust strategies based on feedback
Shared Situational Awareness	When team members have compatible mental models of the environment within and outside of the team.
Performance Monitoring and Feedback	Ability of team members to give, seek, and receive task clarifying feedback.
Leadership/Team Management	Ability to direct and co-ordinate the activities of other team members particularly pertaining to performance, tasks, motivation, and creation of a positive environment.
Interpersonal Relations	Ability to optimise the quality of team members' interactions.
Co-ordination	Process, by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronised and completed within established temporal constraints.

Appendix B

Table B. Coding scheme for examining generic skills within design teams

Generic Skills	Code	Observable Behaviours	Example
Adaptability	A1	**Recognises areas for improvement in design or solution**	"Maybe I should change the size of X"
	A2	**Directs attention of the designer to a possible improvement for the design or solution**	"Maybe you could should change the size of X"
	A3	**Physically fixes or improves a design within 10 seconds of the flaw being nominated**	
Shared Situational Awareness	B1	**Explains a design/solution**	"This bit represents that service area"
	B2	**Asks for confirmation on a design/solution or aspect**	"So this is the service area here?"
	B3	**Asks a question regarding a**	"Where is the service

		design/solution or aspect	area?”
	B4	**Finalises a design/solution**	“OK that’s that drawing done”
	B5	**Distributes relevant written or physical information**	
	B6	**Identifies future problems**	“If you do X it could cause a problem during a later stage”
	B7	**Uses anticipation to complete other team member’s sentences. Usually followed by agreement from the team member**	
	B8	**Identifies a possible source of information**	
Performance Monitoring and Feedback	C1	**Questions or asks for a description of a task**	“What scale are you going to sketch X at”
	C2	**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”
	C3	**Asks for feedback or confirmation on task**	“Your drawing X at a ration of 100:1 aren’t you?”
	C4	**Explains a task**	“I created a cross sectional drawing at the service level”
	C5	**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	D1	**Communicates the instructions and standards described in the design brief (formal)**	Reads from brief
	D2	**Suggests a new task**	“I think we should make a new drawing of section X”
	D3	**Gives priority to tasks**	“We should draw a cross section first”
	D4	**Assigns tasks to team members**	“OK you can do that and I will do this”
Interpersonal Relations	E1	**Spontaneously asks a team member for their opinion on a task or design**	“Hey Pete, what do you think of X”
	E2	**Interrupts another team member with a statement which goes against what the member is expressing or changes the focus**	
	E3	**Conflict/conflict solving**	Arguing/Taking control of an argument
	E4	**Joking, gossip/non-design discussion**	“What are you doing after work?”
	E5	**Polite remark**	“Thanks”, “Sorry”
Co-ordination (task related)	F1	**Checks or monitors the progress of tasks against time**	“We have to finish X by the end of the day”
	F2	**Checks or monitors workload against time**	“OK you have 10 minutes to finish X”

	F3	**Asks a question regarding an artifact/technical problem**	"Where is that drawing going?"
	F4	**Explains the presence or destination of an artifact/technical problem**	"I am putting X over here with the other drawings"