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Detailed Empirical Studies of Student Information Storing in the Context of Distributed Design Team-based Project Work

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This paper presents the findings of six empirical case studies investigating the information stored by engineering design students in distributed team-based Global Design Projects. The aim is to understand better how students store distributed design information in order to prepare them for work in today's international and global context. This paper outlines the descriptive element of the work, the qualitative and quantitative research methods used and the results. It discusses the issues around the emergent themes of information storing; information storing systems; information storing patterns; and information strategy, making recommendations; establishing that there is a need for more prescriptive measures to supporting distributed design information management. This work will be of great value to industry also.

Keywords: distributed design, design management; design studies; design education

Detailed Empirical Studies of Student Information Storing in the Context of Distributed Design Team-based Project Work

Highlights

- *This research identifies a wide range of issues associated with managing distributed design information by global teams of engineering students.*
- *Students' information collections in global project work were often found to be unorganised; lacked structure; were unclear and lacked context.*
- *There is a need for prescriptive support for distributed information management, especially for students.*
- *A series of Recommendations are listed in this paper to address the issues found in the studies.*

Detailed Empirical Studies of Student Information Storing in the Context of Distributed Design Team-based Project Work

This paper presents the findings of six empirical case studies investigating the information stored by engineering design students in distributed team-based Global Design Projects. The aim is to understand better how students store distributed design information in order to prepare them for work in today's international and global context. This paper outlines the descriptive element of the work, *the qualitative and quantitative research methods used and the results. It discusses the issues around the emergent themes of information storing; information storing systems; information storing patterns; and information strategy, making recommendations; establishing that there is a need for more prescriptive measures to supporting distributed design information management. This work will be of great value to industry also.*

Keywords: distributed design, design management; design studies; design education

Globally distributed collaborations and distributed teams are becoming commonplace (Hinds & Mortensen, 2005). However the issues of distributed working are many, with common problems relating to information access and information acquisition the most common. Skills in distributed information management are becoming increasingly important both because of the quantity of information available and because of the increasing availability of IT tools to support information management.

A review of the literature has identified a number of key issues associated with distributed design information storing, such as poor information access and acquisition (Crabtree et al., 1997); difficulties due to the use of technologies; and the time taken to manage engineering design information (Marsh, 1997). Research has mainly focused on the search for, and use of information, with little focus on how information and resources are stored or managed (Nicol et al., 2005). Early work by the author began to identify issues with information storing in an educational context, finding that students' information collections are often unorganised and lack structure; stored information is unclear or lacks context; students find storing and sharing of design information and knowledge in distributed teams time consuming and the tools awkward to use. This can lead to poor project progress and can impact on the quality and success of project outputs (Grierson et al., 2004, 2006). Understanding better how students store distributed design information will be valuable in preparing students to work in today's global context and addressing the lack of prescription or guidance on information management to support designers.

These studies contribute to a gap in the knowledge by presenting the findings of six detailed empirical studies into the information stored by distributed student teams taking part in Global Design Projects, at the University of Strathclyde, Glasgow, UK; Stanford University, USA; Swinburne University, Australia; and the University of Malta. Through both quantitative and qualitative research methods, the paper addresses the key research question - *"How do students store design information and knowledge in a distributed design context?"* i.e. what is stored, where, when and how?

1 *Engineering Design Information*

1.1 *Engineering information management*

Studies have shown that information is fundamental to the process of engineering design development (Bucciarelli, 1984; Minneman, 1991) and that effective engineering management is regarded as fundamental to the successful operation of engineering organisations (Coates et al., 2004). Due to their high dependency on information, companies can gain a competitive advantage and significant improvement in organisational performance and operating efficiency by utilising information and knowledge systems (Hicks et al., 2006). The importance and need to record and maintain design information and knowledge today is even more critical, with the ever-increasing volume of information in engineering design organisations (Zhao et al., 2008); the shift from product delivery to through life service support (McMahon et al., 2005); the need to share informal information as well as formal information (Grierson et al., 2006); and the need to work at extended distances.

There needs to be an understanding of how engineers manage information and yet little is known about the use of information and documents by engineers (McMahon et al., 2004). However, this is changing. Recent in depth studies in information use include – logbook studies (McAlpine et al., 2006); the information content in design documents (McAlpine et al., 2009); studies of engineers' diaries (Wild et al., 2010); and, the use of email in engineering organisations (Wasiak et al., 2010).

1.2 *Distributed Design Information Storing*

The act of distributed design information storing is a process whereby engineering or product development teams work together towards a common goal, using information, separated by distance using a variety of technologies. The information they store supports a shared understanding of the design problem and affords project progress. Project information in teamwork is often poorly managed and used due to a number of factors: lack of time, loss of information, lack of team trust, etc. In distributed team work these issues can be exaggerated and further difficulties exist; for example, difficulties with technologies and communication, or a lack of context. This work focuses on the storing of engineering design information in distributed student design teams.

2 *The Studies Context*

2.1 *Studies Aims and Objectives*

The Aim and the Objectives of the design studies are listed below in Table 1 –

Aim	Objectives	
To understand the information storing behaviour of students working in distributed design team-based project work	**Obj1.**	Establish how students store distributed design information through a series of 'real life' case studies in the context of a *'Global Design Project'*
	Obj2.	Identify the information storing issues that distributed teams experience when engaging in distributed design team-based project work
	Obj3.	Make recommendations for improving distributed design information storing practices

Table 1: Design studies aim and objectives

2.2 *Research Question*

The key Research Question of these studies is - *"How do students store design information and knowledge in a distributed design context?"* i.e. what type of information is stored, where, when and how? Quantitative evaluation includes detailed analysis of archived project information in file repositories, wikis/webpages and emails, and the examination of system logs. The need for a rich and deeper understanding of how and why phenomenon occur, and how student information storing processes may be improved, also requires the use of qualitative research methods, such as questionnaires, examination of student reflective reports and semi-structured interviews.

2.3 *Participants and Design Briefs*

The studies were set in the context of a Global Design Project offered as part of the Global Design Class at the Department of Design Manufacture and Engineering Management (DMEM) at the University of Strathclyde, Glasgow, over a period of 2 years. The Global Design Project was developed through the JISC/NSF funded DIDET Project (Digital Libraries for Distributed Innovation in Design Education and Teamwork: www.didet.ac.uk). UK product design engineering students were teamed with other engineering design students from USA or Australia or Malta. The project gave students experience of distributed design; let them understand the problems that can arise; and allowed them to interact with different collaborative tools, including shared workspaces, wikis, email, video conferencing, and digital repositories. For an overview of the studies' parameters see Table 2.

	Case Study	Partners	Design Brief	Nos of Students	Mode of Working
Study 1	1	Stanford University CA U.S.A.	Design and prototype of a **coffee cup holder** to carry six cups using only cardboard	UK-side = 3 USA-side = 2	**Asynchronous** over 3 weeks - 8 hours (GMT)
	2			UK-side = 3 USA-side = 3	
Study 2	3	Swinburne University Melbourne Australia		Strath-side = 2 Swin-side = 3	**Asynchronous** tasks (follow-the-sun) over 2 weeks + 9 hours (GMT)
	4			Strath-side = 3 Swin-side = 3	
Study 3	5	University of Malta Msida Malta	Design of a **Marathon Running Water Station**, market research to concept design	Strath-side = 2 Malta-side = 3	**Synchronous** – tasks with VC over 2 weeks + 1 hour (GMT)
	6			Strath-side = 2 Malta-side = 3	

Table 2: Overview of descriptive case studies' parameters

3 Research Methodology and Methods

3.1 Research Methodology

Key to the research philosophy underpinning these studies is the interpretivist paradigm to provide a deeper understanding of engineering design students' distributed information storing processes and experiences. Blessing et al.'s *Descriptive/Prescriptive Design Research Methodology* (DRM) has been used as a research framework (Blessing et al., 1998, 2009). These studies present Blessing et al.'s *descriptive phase*.

3.2 Research methods – data collection and data analysis

Figure 1 presents the Research Methods, including the Case Study Method, used to gain an understanding of student teams' design practice and processes (Yin, 2003); Data/Archive Content Analysis, used as a systematic technique for establishing content categories based on rules of coding; Questionnaires and Student Reflection used to gain insight into student information storing behaviours and Semi-structured Interviews to validate findings. Coding, Clustering and Visualisation/Mindmaps drew out findings (Miles & Huberman, 1994; Krippendorff, 2004).

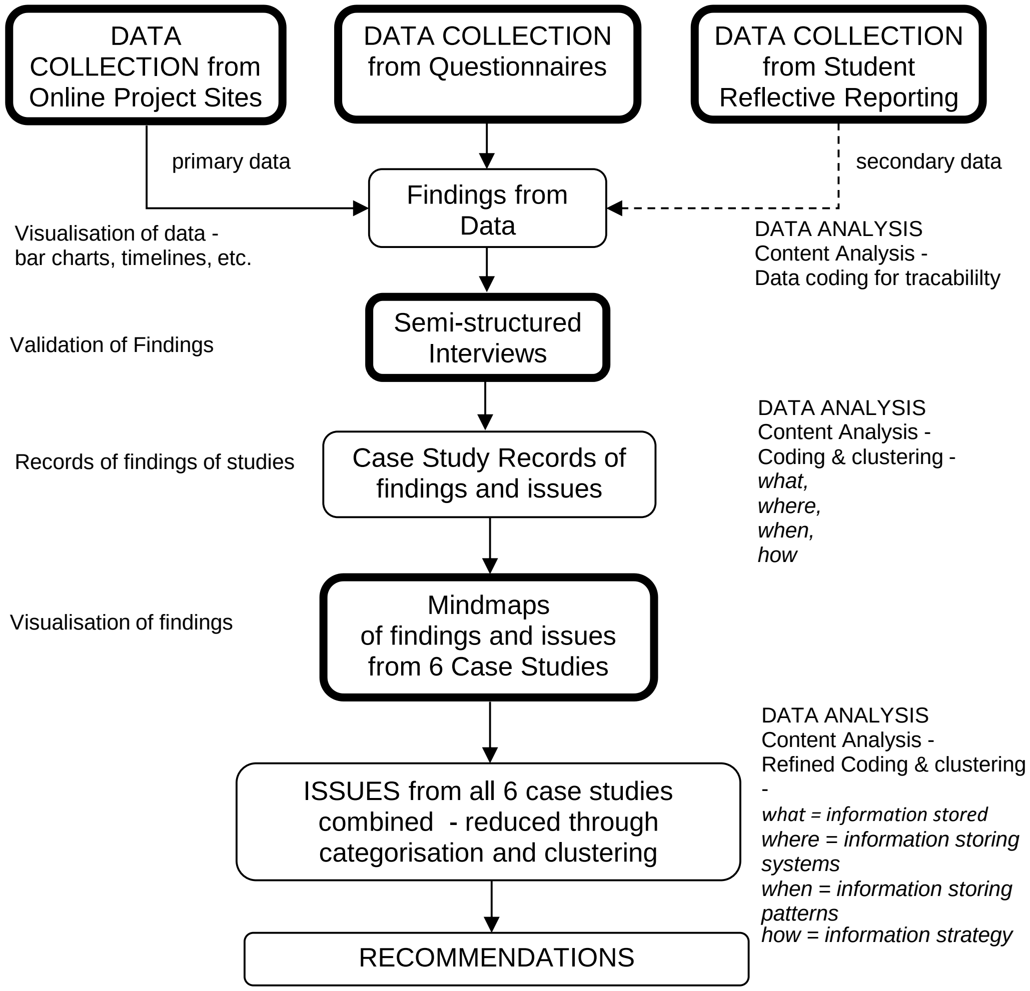

Figure 1: Case study process highlighting research methods used

Each instance of an information content category was recorded. Formal and informal content, information representations and file formats were quantified. System logs provided data for case timelines. All data was visualised using bar charts, timelines and graphics. The quantitative data and qualitative data from each participating team generated a 'picture' of each case's distributed information storing behaviour, which was shown to the UK-side of each global team in a semi-structured interview, in order to validate the data collection. All findings were then coded (in order to be able to keep track of the data) and clustered (into categories). This helped to bring issues to the 'surface' through reducing and simplifying of the data and information, resulting in a series of Case Study Records of all findings. Visualisation using mindmaps was used to draw out the key recurring issues and themes. See Figure 2 for an example of issues resulting from one team study – Case 1.

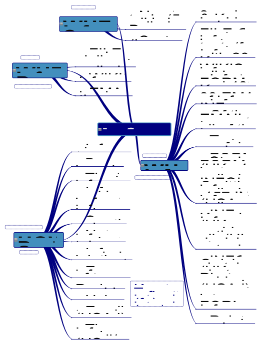

Figure 2: Distributed design storing issues resulting from case study 1

4 *Research Results*

4.1 *What information was stored?*

The studies were concerned with the content and type of information stored by distributed student teams in the process of collaboratively designing a small product. The content of each file, web page and email was examined, firstly to give greater granularity to the results and secondly there was a need to establish whether students were storing more *formal information* (factual and declarative; more product-related) or *informal information* (produced as a result of generating the outputs; more practice-related) and to what extent. An information content classification/coding scheme, tailored to the context of the Global Design Projects was used to examine content stored by teams. Formal information content categories were: *market research; product/user requirements; concepts and testing; calculations; detail design and testing; functional, materials, assembly* and *manufacturing information* and the *final solution*. Informal information content categories were: *design rationale; actions & decisions; problems, social, communications, procedural* and *locational information* and *organisational information* on the *team* and *tasks*. At the macro level the unit of analysis was a web page, or a text file, image file, video file or email message. At the micro level, the unit of analysis was a phrase or sentence within text or annotations on sketches.

The greatest instances of formal information content stored by the distributed teams in their online project sites were on the product itself – *functional information; materials information*; *product/user requirements*; *concepts*; and, *components & assembly information.* The greatest instances of Informal information content stored by the distributed teams were – *contextual information; design rationale*; *actions & decisions*; *locational information*; *social information; communications information; procedural information; problems/issues/questions* and *organisational information on tasks* and *on team.*

In most asynchronous cases the students stored approximately equal amounts of formal and informal information; more informal information than students expected. In synchronous projects it was anticipated that teams would store much less informal information but this proved inconclusive. See Table 3.

		What: files, wikis, emails	**What:** instances of information content	**What:** Formal and Informal instances of information content			
				Formal		**Informal**	
Study 1	**Case 1**	files	161	129	80%	32	20%
		LauLima wikis	233	140	60%	93	40%
		emails	170	2	1%	168	99%
		overall	**564**	**271**	**48%**	**293**	**52%**
	Case 2	files	378	258	68%	120	32%
		LauLima wikis	39	0	0%	39	100%
		emails	131	20	15%	111	85%
		overall	**548**	**278**	**51%**	**270**	**49%**
Study 2	**Case 3**	*Socialtext* wikis	201	102	51%	99	49%
		emails	37	0	0%	37	100%
		overall	**238**	**102**	**43%**	**136**	**57%**
	Case 4	*Google Docs*	112	59	53%	53	47%
		emails	44	3	7%	41	93%
		overall	**156**	**62**	**40%**	**94**	**60%**
Study 3	**Case 5**	Wetpaint wikis	219	98	45%	121	55%
		emails	42	0	0%	42	100%
		overall	**261**	**98**	**38%**	**163**	**62%**
	Case 6	files	213	137	64%	76	36%
		Google Groups	0	0	0%	0	0%
		emails	24	0	0%	24	100%
		overall	**237**	**137**	**68%**	**100**	**42%**

Table 3: Instances of information content stored by 6 team cases

4.2 Where was information stored?

The majority of teams stored design information in a shared workspace or website and email. More organised teams linked the technologies together for easier access to information. Complete details can be found in Table 4.

4.3 When was information stored?

Uploading of files tended to take place around project deliverables and at the end of projects. Peaks occurred at the end of weekly research, concepts and prototyping stages. Contributions to web pages were more evenly spread throughout the projects' see Figure 3.

		Where was Information Stored	
Study 1 (Asynchronous)	Case 1	*LauLima* file galleries – files	69 files across 2 file galleries (68 image files & 1 text file)
		LauLima wikis	31 wikis - 4 levels; 56 links to other wikis or files
		University email	39 emails – 5 attachments (also in Laulima)
	Case 2	*LauLima* file galleries – files	41 files across 2 file galleries (27 image files, 8 text files, 5 wikis, 1 PPT)
		LauLima wikis	10 wikis - 2 levels; 9 links to other wikis or files
		University email	41 emails – 31 attachments (also in Laulima)
Study 2 (Asynchronous)	Case 3	*Socialtext – wiki pages*	5 wikis - homepage + 4 33 files (all image files embedded in wiki pages)
		University email	5 emails - no attachments
	Case 4	*Google Docs – web pages*	5 web pages - homepage + 4 2 files (pdfs of PPTs also on Google Docs web pages)
		University email	8 emails – 1 attachment (uploaded to *Google Docs*)
Study 3 (Synchronous)	Case 5	*Wetpaint – wikis*	9 wikis – 3 levels (14 links to wikis and to 1 pdf) 1 file (pdf linked to wiki)
		University email system	11 emails
	Case 6	*Google Groups – web pages*	1 web page – storing files; no other information 5 files – 2 image files, 3 Word docs with text and images
		University email	5 emails
		University email	5 emails – 3 *SolidWorks* attachments

Table 4: Where information was stored by 6 team cases

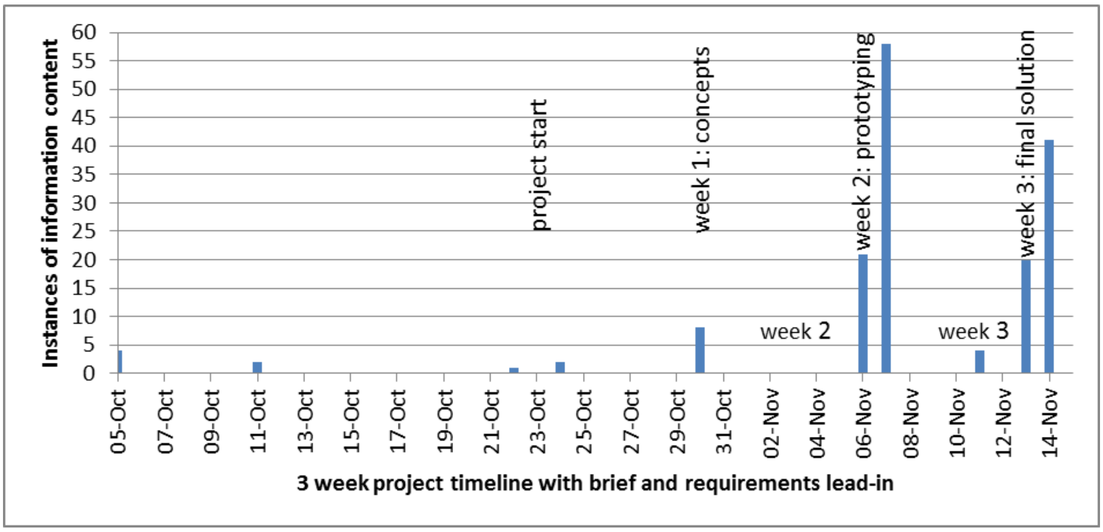

Figure 3: Uploading of files tended to peak at key points in project

4.4 *How was information stored?*

A wide range of information representations were used (see Table 5), with text being the most commonly used. Photographs were highly valued for their ability to reach a shared understanding. Students stored a range of typical file formats e.g. text (.doc, .txt); image (.jpg, .gif, .png, .bmp); video (.mov, .avi); presentation (.ppt) and spreadsheet (.xls), in addition to pdfs.

How: Instances of information in information representations		**Text (%)**	**Photos of physical models/objects/**	**Photos or scanned sketches (%)**	**CAD drawings (%)**	**Images form Internet (%)**	**Spread sheets (%)**	**Video (%)**
Study 1	Case 1	√	√	√	-	√	√	√
	Case 2	√	√	√	-	√	-	√
Study 2 and 3 were more detailed, further exploring percentages of instances of information content in information carriers.								
Study 2	Case 3	62	38	-	-	-	-	-
	Case 4	65	21.5	7.25	6.25	-	-	-
Study 3	Case 5	81	3.5	-	14	-	1.5	-
	Case 6	68.5	-	21	-	10.5	-	-

Table 5: Information representations used across 6 cases

5 *Discussion of the Issues*

5.1 *Information Storing: what information was stored?*

5.1.1 *Amount of information*

It was evident that not all project information collected and generated by teams was stored. On the asynchronous projects UK students reported that between 50-70% of information was stored. Time impacted upon the amount of information which could be stored. The opportunity to discuss work via video conferencing (VC), also affected the amount of information stored. On synchronous projects UK students noted this reduced to about 45-50%. Students reported the more they communicated face-to-face (via VC) the less overall project information they stored. One of the aims of storing and recording project information is to capture a comprehensive and rich picture of the product, project and its processes. Lack of recording of informal information on student design projects can create an incomplete picture of work on a project. In some cases – sketches lacked rationale; changes needed explaining; decisions needed clarifying, etc. Verification caused delays.

With the exponential increase in available and generated information, students need to be able to evaluate and assess information and reduce the amount of appropriate information to be stored. Students found this hard to do. Students also reported that too much information contributed to a loss of focus; storing of unnecessary information wasted time; and information was often not re-visited if it was lengthy. However, information 'under load' should also be avoided as this can severely affect decision-making and product outcomes. Some students reported an element of frustration that their global partners had not contributed to information storing. They regarded equal contribution to storing as equal engagement.

5.1.2 Information Content – Formal and Informal

Traditionally students share and retain the more formal documentation, e.g. the selected *concepts* and *final solution*. This reflects current practice in design education - more product-focused than practice-focused. However informal information content categories (e.g. *design rationale*, *decisions* and *organisational information*) have high value in terms of student learning. On the asynchronous distributed work students were surprised to find that they had stored approximately equal amounts of formal and informal information; expecting far more formal information. On synchronous projects informal information was generated and discussed but less likely to be recorded. The findings did corroborate the premise that socialising increases collaboration and informal communication is a driver for successful teamwork. In a distributed context there is greater need for and reliance on informal information to make sense of the more formal documentation. Distributed partners appreciated receiving not only the design work and changes but more importantly the rationale for design changes. Students also noted that *organisational information on the team* and *tasks* were useful to store and share to keep everyone aware.

There is the potential for the creation of links and relationships between informal information and the more formal project information and documentation without too much additional time and effort. Students need to make these relationships much more explicit; for example through the hyperlinking of wiki pages and signposting of information.

5.2 Information systems: where was information stored?

5.2.1 Need for a centralised information storing tool

Overall students' information management skills were found to vary and at times to be lacking. Several students had a poor information storing experience; finding that using too many systems meant information was fragmented and duplicated. They became frustrated and communication weakened as a result. Students in the studies recognised the need for a centralised information store to support the management of their distributed information and that access to centralised information made decision-making easier. Students were aware of the high importance placed on the retaining of information in industry and recognised the need to store project information in practice.

5.2.2 Awareness of information

One of the most frustrating aspects of distributed information storing for the students was the time lost trying to locate information. All students agreed that a distributed team needed to know or be aware of where project information was stored in order to achieve quick and successful retrieval of information.

5.2.3 Selection of technologies

Shared workspaces, by themselves, may not be sufficient to support certain collaborating groups (Subrahmanian & Jellum, 1998). Students found this to be the case. The use of a communications tool with their information storing tool was especially beneficial. A high number of instances of informal information content were found in email communication.

At focus groups students expressed concern at being tied into technologies at the beginning of a project and preferred to adopt a framework which afforded adaptability with the introduction of new (and integrated) technologies, when required. They were unanimous that any technology should not impede the design process and that tools must have an acceptable learning curve; and be simple and quick to use. Such tools as *Socialtext, Google Groups, Google Docs* and *Wetpaint* satisfied these information storing requirements as: information could be stored and uploaded easily; information could be found easily and time was minimised.

5.2.4 Familarisation with tools

More than 50% of the teams started project work without sufficient knowledge of the tools, causing some confusion and delay to the start of product development. However technology-related information storing issues tended to be minimal, relating to registering or initial accessing of stored information. Wikis were popular information storing tools with four of the six distributed teams noting they were already familiar with wikis and a web environment and that information could be scrolled through and viewed more easily than having to open files and refer to their content.

5.2.5 Longevity of information

In an educational context, online project information stored throughout project work helps students achieve a shared understanding of the project problem; it helps support decision-making and project progress. Students were able to access shared project information during the project and also several weeks later for report writing and examination purposes. The information stored by students has additional educational value in terms of staff re-use of material as good exemplars.

5.3 Information Storing Patterns: when was information stored?

5.3.1 Uploading of project work

Not storing information at the time of generation was shown to weaken collaborative decision making, and slow project progress; with sides of teams unable to act effectively on incomplete information. Any prolonged gaps in information exchange not only caused frustration and halted project progress but also led to a questioning of global team commitment and engagement. Students found information needed to be stored and shared in a timely manner in order not to impact or impede project progress. The teams who maintained a continuous flow of information showed better team cohesion and had a more collaborative experience.

5.4 *Information Strategy: how was information stored?*

5.4.1 *Information Representations*

A wide range of information representations were used across the teams to externalise, store and share distributed information – *text; photographs of physical models/objects/people; photographs or scanned sketches and notes; 2D/3D CAD drawings; images from the internet; spreadsheets;* and *video*. Students reported the key to selection was time – whichever methods proved quickest dependent on the skills and knowledge of the global team members.

Text was the most common and preferred information representation used to store and exchange instances of information content. However, students reported it was often hard to describe project work using words alone. Students regarded photography highly; most often using their readily available phone cameras. Photographs were easy to produce and store; they captured *model making/ prototyping* and the *final solution*; they demonstrated how things worked; and they contained valuable *materials information, components & assembly information, contextual information* and *social information*. Students reported that video was good at conveying meaning; demonstrating product attributes; hosting informal information; and an informative method for the exchange of information. However they reported several drawbacks. It was time consuming to produce and to view; and once viewed it was hard to locate and pinpoint specific information. They suggested the use of several short informative clips rather than long video recordings. Overall students found a multi-media approach most suitable - a combination of text with photographs; text with CAD drawings; or text with sketches.

5.4.2 *Need for strategy and rules*

'Remoteness' makes the management of information particularly complex and the need to develop a strategy and establish rules are even greater due to reduced opportunities for discussion and increased potential for misunderstanding. Examination of online project sites showed that in most cases information management was ad hoc. Students noted that lack of time and not knowing their global partners well enough, contributed to strategy or rules not being made early on, which proved somewhat counterproductive. Students noted that any information storing strategy should be adaptable to accommodate project work at different stages.

5.4.3 Structuring and organising information

Several of the teams' information sites were unorganised and lacked structure meaning shared information was difficult to find. Previous work of the author (Grierson et al., 2005) and studies in industry (Davis et al., 2001) have shown the importance of structuring project information. Organised information can be turned around more effectively and efficiently allowing informed decision-making.

Other research suggests that constructing resource collections contributes to learning by requiring that students analyse, organise and reflect on their knowledge (Jonassen & Carr, 2000; Denard, 2003).

5.4.4 Clarity of information: adding context

In distributed design there is a greater need for information clarity due to the lack of opportunities for explanation and the absence of key context providers such as people, place and time. At times during the studies, teams found that information wasn't sufficiently clear which often led to delays, confusion and frustration. Time impacted on information clarity. However, ensuring that information was clear to distributed partners engaged students in deeper cognitive activities. One team reported it made them think harder.

Students found they needed to record and store more context and justification during distributed design, compared with collocated design, in order to avoid misunderstandings or ambiguities. Formal information and documentation alone was not enough. Informal information added meaning and context, making for a richer description of the design process; but storing of this information took extra effort and time. Linking information or clustering it with other information gave information greater meaning. This not only helped students construct a clearer picture of the project problem but it afforded greater meaning to the information when viewed out of context or at a later date. Multi-modal communication channels provided context for the interpretation of remote information. Students found the informal information content contained in emails or other communications helped to clarify information in files, documents and on web pages. So a conflict arises between the need for distributed information to be more concise whilst at the same time richer and more detailed. Additional time and activities designed into distributed project work can help student teams achieve both aspects.

5.4.5 *Reflection on and interaction with stored information*

Re-visiting of stored information during the distributed projects was limited across all six cases due to tight timescales. Research has shown that in practice students tend to focus on finding content, rather than reflecting on and evaluating its significance relative to the problem in hand and to project progress (Nicol et al., 2005). This is still of key concern to educators.

The above section discusses the key issues identified by the studies. A comprehensive record of issues across all 6 case studies is presented in Table 6. A series of Recommendations are also proposed in Table 6 to improve future distributed information storing practices. These will not be discussed here but future work intends to evaluate implementation of these recommendations.

ISSUES and FINDINGS from Cases	**RECOMMENDATIONS**	
• Lack of recording of informal information created an incomplete 'picture' in some cases. • Amounts of information stored varied across teams. • Students were unsure of what to store – too much or too little. • Not all information had been stored by teams. • Less Informal information was stored on synchronous projects due to greater opportunity to discuss via VCs. • UK-sides stored more than distributed partners. This caused frustration in some teams.	• *Recommendation to store and record a comprehensive 'picture' of project problems, processes, rationale and outcomes.* • *Recommendation that not all information needs to be stored; avoid information 'overload'.* • *Recommendation to avoid information 'under load'.* • *Recommendation to contribute equally across distributed sides of a team to avoid inequality and frustration.*	**What:** information storing
• Students traditionally store formal documents required as deliverables or final solutions, which are invariably tied into assessment. • Storing *functional information, product/user requirements* and *materials information* helped reach a shared understanding on projects. • Students find storing Informal information time consuming. • Students reported they would store more informal information if they received more marks. • Students recognise the importance of design rationale and contextual information in distributed design. • Students felt more information could have been stored on the design process.	• *Recommendation that Formal information is stored on the product.* • *Recommendation that Informal information is stored on product, process and people in order to support development during the project and add meaning to the Formal documents.*	
• Across all systems, almost equal, or more Informal information was stored in the Project Memories. Students did not expect this. • Files contained more Formal information – e.g. final solution and deliverables. • Wikis were valuable for storing Informal information. • Emails contained high %s of Informal information content.	• *Recommendation that at least half of information stored is informal to add context and meaning to formal documents.* • *Recommendation to store more Informal information when working asynchronously.*	
• Information stored in different places resulted in delays in finding information. • Access to information at all times was beneficial. • It was confusing having several ways or places to store information. • Using too many systems meant information became fragmented and duplicated.	• *Recommendation for centralised information storage in distributed design team work.*	**Where:** information storing systems
• Recording information was time consuming. • Information storing and communication systems worked well together. A synchronous team noted the reverse too – a communication tool alone is not sufficient; an information storing tool is also required. • Difficulties with information storing contributed to a lack of communication.	• *Recommendation for tools to satisfy distributed information storing needs, including adaptability.* • *Recommendation for communications tool to support information storing tool.*	

• Simple systems with an acceptable learning curve were preferred by students.	• *Recommendation for selected tool(s) to be simple to use so as not to interfere with the design process.*	
• Teams found being unfamiliar with system problematic. • Time is needed to become familiar with system prior to project start. • Unequal systems competencies caused inequality within teams.	• *Recommendation for all global students to be familiar with tools prior to the start of the project.*	
• Information stored in 'temporary' locations was lost to teams. • One tool only stored information for a limited time; thus losing project information before report writing.	• *Recommendation for selected tool(s) to retain information and for it to be accessible for the duration of the distributed project, and beyond for academic purposes (e.g. student reflection, staff re-use, external assessment and research).*	
• Time was lost locating and finding information. • Access to information storing systems was initially confusing and caused delays. • There was some initial confusion as to where information lay. • Lacking or missing information caused delays.	• *Recommendation for all global students to be able to find information easily and quickly.*	
• The more formal project information tended to be stored on completion of key stages. • Wiki changes were slightly more evenly spread across project duration. • Decisions were dependent on timely information. • Generally one person on each side stored project information. • Asynchronous work created a distinct start-stop storing of information by each side of a team. Two independent sides evolved carrying out and exchanging concept designs. • Information storing format of initiating side of team is followed by other side. • Synchronous work was far more collaborative. Information tended to be stored more continuously.	• *Recommendation to record, store and share information as events happen, or as information is generated, by all global team members, in order to benefit everyone and support distributed collaboration.*	**When:** information storing patterns
• *Text, photographs of models/objects/people, photographs of scanned sketches* and *video* were the most common information carriers. • Text documents and images were richest in information content. • Photographs made for good evidence and were quick and easy to produce and store. • Students found it hard to be clear and concise using text alone. Text and photographs; or text and sketches or 2D CAD sketches were a good combination. • Video was good for exchanging information but was time consuming to produce or view on a short project. • Key points from VC meetings were recorded and stored, but not VC sessions. Students noted these would not be revisited due to time.	• *Recommendation for distributed design to support all information carriers as appropriate to project requirements, e.g. text, sketches, CAD drawings, photographs, video and audio.* • *Recommendation for students to recognise the advantages and disadvantages of different information carriers and to determine their appropriate use in distributed work.* • *Recommendation to record video as short clips.* • *Recommendation to record summary/outcomes of real-time VC sessions. Full transcripts and records seldom revisited due to length.*	**How:** information strategy

• Information storing was often ad hoc. • Most teams did not discuss rules for storing project information before the project start. • Information storing evolved. • One team felt that in order to discuss information strategy they needed to know all global team members. • This team also felt turn-based nature of asynchronous design contributed to the lack of a joint information storing strategy. • Lack of time, was most reported as contributing to a lack of strategy or rules. • Any strategy should be flexible and capable of being adapted to some extent, dependent on information storing requirements as project work develops.	• *Recommendation for global student teams to establish rules for storing of distributed project information – what to store (content & information carriers); where to store information (tools); how to store it (organisation/who) and when to store it (working patterns).*
• Lack of organisation and structure to project information caused frustration and confusion. • Students recognised need for organising and structuring. • Students find structuring information hard. • Few teams had structured their Project Memories – some by time, on wikis/web pages, others by design stages.	• *Recommendation for distributed design information to be structured and organised.*
• Asynchronous design required information clarity; ambiguity had to be reduced; nothing could be assumed. This was additional to collocated work. • Time was spent making information more concise and informative. This forced students to think. • Short project timescales affected clarity and completeness of information.	• *Recommendation for distributed design information to be unambiguous and clear.*
• More context was needed in asynchronous work. • Distributed information requires more explanation.	• *Recommendation for information to be richer and more detailed in a distributed situation than in a collocated situation.* • *Recommendation for information with more context.*
• Informal information exchanged via communication tools helped clarify information in files and on web pages. • Need to keep communications levels high.	• *Recommendation that since communications tools stored valuable Informal information that this information be regarded as part of the store or linked to the repository.*
• Students reported not referring back to information much.	• *Recommendation for interaction with and reflection on stored project information during project time, for increased student learning.*

Table 6: Summary of all findings and recommendations from 6 case studies

6 *Summary and Conclusions*

A unified central store proved more suitable than information stored in several places. Systems required to be secure and retain information for as long as necessary - for use as exemplars, student reflection, staff re-use; external assessment, research, etc. Due to the indeterminate and unpredictable nature of the design process it is often difficult to anticipate all information storing requirements prior to a project start. Allowances should be made for the adaptability or introduction of new tools.

The studies have shown that a lack of familiarisation with the use of the technologies resulted in some teams not finding information quickly and easily, early on. This caused frustration; reduced team cohesion and impacted negatively on project progress. Time has to be factored into the design of any global project for preparation. In instances of poor or no communication, students tended to turn to the technologies they were most familiar with for example, mobile phones or email. This has implications for information storing. Critical information can be lost as phone conversations and email are not naturally retained as part of project information by students.

Storing distributed design information is challenging. Today there is a tendency for the 'Google generation' to find far too much information, all too quickly and for this information often to be of questionable quality. Firstly, in distributed design several of the key context providers for information are missing, for example people, place and time. As such there is the need for greater storing and sharing of informal information. Secondly, students reported informal information can be 'long and messy'. It takes time to add or to link existing informal information to the formal project documentation. Educators and students need to allow additional time to make information meaningful and clear. Thirdly, students found it hard to determine how much information to store. Recommendations from the Case Studies suggest that in distributed design team-based project work at least 50% of stored project information is informal information. Fourthly, students need to develop greater skills in self-evaluating information and educators need to build such tasks into project work in addition to guidance and advice.

Students need to store information frequently throughout a distributed project. Failure to do so will cause frustration within global teams; affect team cohesion and trust; and hamper decision-making and project progress.

Without a clear strategy or rules for storing and sharing distributed design information the quality of project information can be affected. Information can be lost or duplicated; be inappropriate or untimely, resulting in a lack of project direction, time wasting, confusion and disagreement; and, in some cases a poorer product outcome. Time needs to be set aside at the beginning of projects, not only to understand the project scope and problems; to socialise with distributed team members and to familiarise with technologies but, also to determine how distributed information will be handled.

The process of organising project information and resources is beneficial. It encourages students to think. Organised and structured information can be turned around effectively and efficiently, allowing others to work based on decisions made. Graduates who have these organisational abilities will be better prepared for industry. Additionally, information can be given increased meaning by linking it or clustering it to other information and creating relationships between 'nuggets' of information. And finally, storing of online project information is critical for project interaction and reflection. Construction of resource collections contributes to learning by requiring students to analyse, organise and reflect on their knowledge, and that of others. Interaction with information keeps team members updated during a project; increases project awareness and promotes a feeling of collaboration. Reflection is recognised as valuable for informing performance improvement; for learning and for development.

Evidence from the empirical studies has identified many issues with distributed design information storing. Indeed there is a need to support students' storing of design information in distributed project work. The series of Recommendations outlined in Table 6 begin to address these issues and future studies will evaluate their effectiveness. Educators require to make students aware of the benefits of maintaining an organised online project information store e.g. a shared understanding of project problems; team awareness; reflection; learning from past experiences (even failure); and preparation for industry (Grierson & Ion, 2008).

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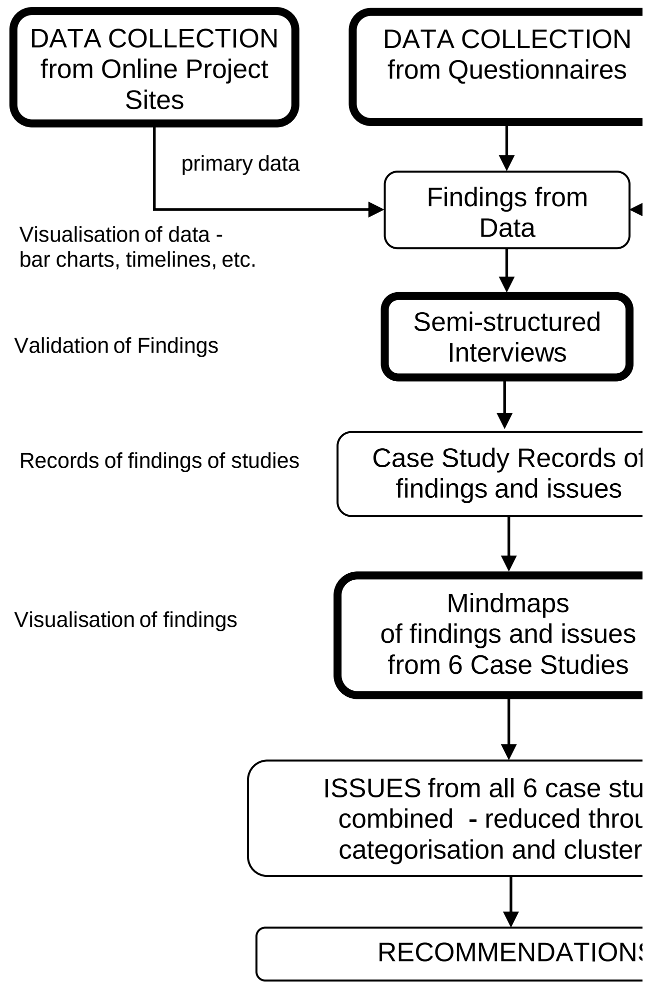
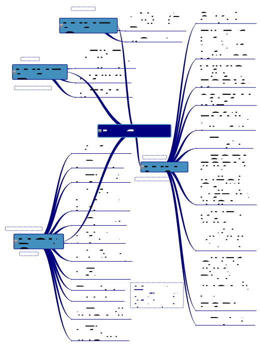
Figure


DATA COLLECTION from Online Project Sites
DATA COLLECTION from Questionnaires
primary data
Findings from Data
Visualisation of data - bar charts, timelines, etc.
Semi-structured Interviews
Validation of Findings
Case Study Records of findings and issues
Records of findings of studies
Mindmaps of findings and issues from 6 Case Studies
Visualisation of findings
ISSUES from all 6 case stu
combined - reduced throu
categorisation and cluster
RECOMMENDATIONS

Figure



Figure

5. filedata + time   *

Team 5
file galleries

date	**Content by info type (instances of)**	
05/10/2006	social info	3
	contextual info	1
06/10/2006		
07/10/2006		
08/10/2006		
09/10/2006		
10/10/2006		
11/10/2006	social info	2
12/10/2006		
13/10/2006		
14/10/2006		
15/10/2006		
16/10/2006		
17/10/2006		
18/10/2006		
19/10/2006		
20/10/2006		
21/10/2006		
22/10/2006	contextual info	1
23/10/2006		
24/10/2006	contextual info	2
25/10/2006		
26/10/2006		
27/10/2006		
28/10/2006		
29/10/2006		
30/10/2006	market research	2
	materials info	1
	functional info	1
	contextual info	2
	organisational info on team	2
31/10/2006		
01/11/2006		
02/11/2006		
03/11/2006		
04/11/2006		
05/11/2006		
06/11/2006	concepts/ideas	8
	project/user requirements	3
	design rationale	2
	functional info	6
	materials info	1
	contextual info	1
07/11/2006	concepts/ideas	6
	components & assembly info	7

	fg
05-Oct	4
06-Oct	
07-Oct	
08-Oct	
09-Oct	
10-Oct	
11-Oct	2
12-Oct	
13-Oct	
14-Oct	
15-Oct	
16-Oct	
17-Oct	
18-Oct	
19-Oct	
20-Oct	
21-Oct	
22-Oct	1
23-Oct	
24-Oct	2
25-Oct	
26-Oct	
27-Oct	
28-Oct	
29-Oct	
30-Oct	8
31-Oct	
01-Nov	
02-Nov	
03-Nov	
04-Nov	
05-Nov	
06-Nov	21
07-Nov	58
08-Nov	
09-Nov	
10-Nov	
11-Nov	4
12-Nov	
13-Nov	20
14-Nov	41
15-Nov	
	161