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TOWARDS A SET OF PRINCIPLES FOR DISTRIBUTED-DESIGN INFORMATION STORING

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ABSTRACT
This paper discusses the development of a set of guiding Principles with a Framework to support distributed design information storing (d-DIS), informed by the findings of several studies into the information and knowledge stored by distributed teams of engineering design students whilst undertaking synchronous and asynchronous distributed design project work. Quantitative analysis of archived data and the use of qualitative research methods, such as questionnaires, semi-structured interviews and reflective focus groups, examine the key research question - *"How do students store design information and knowledge in a distributed design context?"* i.e. what type of information is stored, where, when, how and why. The paper also presents student and staff feedback on these initial guiding Principles through workshop-style focus groups and concludes with an overview of the refined Principles based on feedback and further development.

Keywords: engineering education, principles, guidance, framework, distributed design information

1 INTRODUCTION
Literature has shown that a significant amount of time is spent managing design information rather than focusing on the design task itself. Engineers spend as little as 15% of time doing analytical tasks and the rest of time is spent negotiating and locating information. [1, 2] Designers spend at least 24% of time sourcing or locating relevant information and knowledge during project work. [3] Project information in teamwork is poorly managed and used due to a number of factors, e.g. difficulties with the technologies, lack of time, poor communication, a lack of team trust, etc. Students also experience these issues. Their information collections are often unorganised, contain unclear information, lacking in context. This can lead to lack of or loss of project progress and impact directly on the quality and success of project outputs. This is further compounded in a distributed situation. In distributed team work problems relating to information access and information acquisition are the most common. [4] To support distributed design collaboration it is crucial to provide an archive or repository that functions as a collective memory. [5] Other research in networked learning has shown that groupware technology can support collaborative learning through the creation of a shared information workspace.[6, 7] Also, constructing resource collections contributes to learning by requiring students to analyse, organise and reflect on their knowledge. [8] Studies at Bath and Bristol, in the late nineties, show designers poorly managing information and knowledge available from suppliers and that at that time there existed no prescription or guidance on information management for designers. [9] Likewise from a number of studies into the understanding of distributed team information storing processes, undertaken by first author [10, 11, 12], it was found that students required guidance on distributed information storing to support their global design project work. A set of guiding Principles for both students and academics would be beneficial. These are introduced in this paper.

2 STUDIES AND FINDINGS
Three studies involving 8 distributed teams were conducted. The key research question of the studies was - *"How do students store design information in a distributed design context?"* i.e. what type of information is stored, where, when, how and why? Qualitative research methods were used to gain a richer understanding of how student information storing processes and experiences could be improved, e.g. examination of student reflective reports, questionnaires, student focus groups and interviews. Quantitative evaluation was also included through a detailed analysis of archived project information.

2.1 Context for studies

All studies took place in the Global Design Class, a 5th year class offered to product design engineering students at the Department of Design, Manufacture and Engineering Management (DMEM) at the University of Strathclyde, Glasgow. The class gives students hands-on experience of distributed design; lets them understand the problems that arise; gain exposure to cultural differences; and offers interaction with different collaborative tools, including shared workspaces, information storing technologies, video and desktop conferencing, and digital repositories, with global partners. Study 1 examined the project information stored by 2 student teams from the University of Strathclyde and Stanford University on a 3 week project, in academic session 2006-2007. Distributed teams were tasked with collaboratively designing a coffee cup holder. Teams comprised of 3 UK students and 2 or 3 USA PhD engineering students. Each team was assigned a UK and USA coach. Study 2 examined the project information stored by 3 student teams from the University of Strathclyde and the Faculty of Design at the Swinburne University of Technology, Australia, on a 2 week asynchronous project, in academic session 2007-2008. Each team, comprising 2 UK students and 3 Swinburne 4th year product design engineering students, was also tasked with designing a coffee cup holder. In Study 3 the same UK students as in Study 2 teamed up with 3rd year mechanical engineering students from the Department of Industrial & Manufacturing Engineering at the University of Malta to design a water station for marathons over 2 weeks. Teams comprised 2 UK students and 3 Maltese students.

2.2 Findings

The information stored by the 8 student teams in the context of global design projects was analysed. The different types of information were closely examined: the formal information (i.e. factual, declarative: the stuff of facts, books, manuals, patents, drawings, reports, etc.) and the informal (e.g. the more procedural and organisational aspects; e.g. rationale, assumptions, decisions, experiences, stories). The different information content e.g. market research, materials, concepts, decisions, actions, etc; the media types, e.g. text, sketches, images, video, etc. stored by the students were also scrutinised. When this was done and what systems were used were also examined. Questionnaires and semi-structured interviews with the students helped to understand why such information had been stored by the teams. The findings for each study were categorised and tabulated around the issues of information storing (what they stored); the tools, technologies and systems (where they stored information); information storing patterns (when they stored information); and the development of a distributed design project information strategy (how they stored information).

2.2.1 Information storing

The information stored by the teams showed only a partial and often fragmented picture. In Study 1 Team 2 reported that on reflection, "*…not enough information had been stored on the actual path to get to the concepts and product*." Students noted via the questionnaire that they stored less information than they generated, as it was time consuming to store. Of the formal information, the greatest instances stored were about the product itself, e.g. requirements, materials, components, functional information, concepts and ideas; these tended to be text and photographs. Storing this type of information helped reach a shared understanding of the project problem. Of the informal information, the greatest instances stored were about the project and team context, information on actions & decisions and design rationale; these were often stored as annotated text notes. Instances of informal information were also high in video, and audio of stored meetings. Text was the most common way of storing information but students found it hard to be clear and concise. Photographs and video often offered up a solution as they were simple and quick methods to capture information but they required explanation, and took time to interpret and view. The greatest percentage of informal information was stored in teams' emails which clarified content in the repository. However, students reported they did not often refer back to stored emails. Previous work has shown that distributed teams need multi-modal communication channels to provide context for the interpretation of remote information. It would be beneficial to link the formal information in a repository to the informal information stored in communications technologies to give added meaning and context; reduce misunderstanding and to save time locating information. [13] A stored MSN meeting conversation was found to be very useful for non-attendees to clarify decisions made. In Study 3, distributed but synchronous project work, it was found that sharing informal information increased team cohesion, however, the more students communicated face-to-face and got to know their partners, the less they stored.

2.2.2Information storing systems

One of the most frustrating aspects of distributed information storing for the students was the time lost tying to locate information. This identified a need for a unified central archive rather than information in several places. They realised that not enough consideration had been given to the choice of tools to be used, either. Tools had to be simple and quick to use; easy to access; and both sides of a team ought to be able to use the tools at equal skill levels. Those more familiar with the tools saw them less of a barrier and tended to be the ones storing information on behalf of the team; adding to some team members being unaware of where information lay. Several teams reported that using communication technologies alongside information storing systems worked well. They helped clarify the information stored in a repository. One team in Study 2 used a time-limited version of a tool which expired before the submission of their reflective reports. These students found it difficult to remember project details.

2.2.3Information storing patterns

Project information tended to be stored on completion of key stages of work by each side of the team, set by the class structure for the projects. Students felt they should have recorded events more often, and as they happened, as information & knowledge recorded sporadically disadvantaged team decisions and reduced collaboration. However, this took time away from other design activities. In asynchronous work, e.g. with Strathclyde and Swinburne, there was a distinct 'start-stop' to the information flow which caused delays; and affected communication and project progress. Analysis of logged data also evidenced leading and following team sides, counterproductive to collaborative working. In more synchronous situations, e.g. Strathclyde and Malta, students tended to store information more regularly but stored less information overall, due to online f2f meetings.

2.2.4Developing a Distributed Design Information Strategy

The nature of design necessitates the use of a wide range of information types and content across many media types. Added to this, 'remoteness' makes the management of distributed information even more complex. Information storing was often ad hoc. During project work teams experienced times when information couldn't be located as it was stored in several places; leading to confusion, duplication and difficulties in sharing. They felt that an information strategy at the beginning of the project would have helped clarify issues. They suggested it needs to outline what information to store, where, when and how. Previous work of the author [10] and studies in industry [14] have shown the importance of structuring project information. In all student studies the need for organisation and structure was recognised. Organised information can be turned around more effectively and efficiently allowing informed decision making. There was also an awareness of a need to record more than usual when working in distributed design in order to avoid misunderstanding or ambiguity. This takes time but it also affords opportunities for students to interact more with the information they are finding and generating, and to reflect on it. It forces them to think.

2.2.5Performance and Project Outcomes

Generally speaking, those teams who familiarised themselves with tools before a project start and stored a wide range of both formal and informal information, using a variety of media throughout the project, were found to perform better as a result of reduced levels of frustration due to time wasting. The best solution to a project problem came from a team who organised and managed their project information, communicating information location; whereas, the weakest project outcome came from a team plagued by information and communication problems. These included, a lack of uploading of research and concept work due to unfamiliarity of tools; the use of another system, unknown to other side of the team; information in several places; resulting in an inability to move the project forward. Some students reported that poor information storing practices caused frustration impacting on student satisfaction with project progress and processes and also their satisfaction with the project outcome.

2.3 Recommendations

The findings for all three studies (8 case studies) were then used to produce a set of recommendations for design information storing to support distributed team work, around the issues of information storing; information storing systems; information storing patterns; and the development of a distributed design project information strategy. These are summarised in Table 1.

Table 1. Summary of Recommendations based on findings of all 3 studies.

What:	**Where:**
Information Storing Determine types of information to store. Determine how much information to store - not all information needs to be stored. Store a complete 'picture' of design. Store more rationale. Images and video help a shared understanding. Increase informal information for context and for increased team cohesion. Communication provides context for stored information.	Information Storing Systems Consider tools carefully at start. A need for a communication tool also. Be familiar with tools prior to project start. Tools need to be simple and quick to use. Maintain a unified central archive; link all tools. Aim for equal skill levels across team. Know where information lies.
When:	**How:**
Information Storing Patterns Record events as they happen. Avoid only recording at deliverable times and make best use of working around 'clock'. Store needs to be accessible 24/7. Keep communication levels high throughout.	Distributed Design Information Strategy Develop a strategy and establish rules. Determine media types to be used, text, photos. Information needs to be organised and structured. Information need to be clear, have clarity. Link informal information to formal information. Make use of stored information during project. Reflect on information for increased learning. Equal contribution across team members. Increase team trust.

3 PRINCIPLES FOR DISTRIBUTED –DESIGN INFORMATION STORING

From the findings of the studies it is evident that students undertaking distributed-design team work require additional guidance to help them overcome the issues associated with storing distributed-design information, e.g. lost and incomplete information, lack of context, poor communication, unable to find information, lack of team trust, etc. Studies at the University of Twente [16] into WWW supported project work in higher education also show this. They highlight the requirement for additional support in terms of workflow management; storing and sharing of information and resources; recording of decision making and progress, and the failure of students to plan and reflect. A set of guiding Principles and a Framework for distributed-design information storing are proposed which should help students to - (i) develop a distributed design project information strategy, (ii) manage and share project resources, (iii) achieve a shared understanding of the project problem, (iv) enhance distributed team communication, (v) create a rich and meaningful story of project problems, challenges, processes, rationale and outcomes, and, (vi) reflect on project processes, group and individual performance and learning achievements. The Principles and Framework have been derived from early work on Project Memories, by first author [11], current literature, the findings and issues identified from the studies, along with the recommendations in Table 1.

By definition (Webster's dictionary) a principle is basic truth or law or assumption; a generalisation that is accepted as true and can be used as a basis for reasoning or conduct. Current work by others in higher education has shown Principles to be an effective tool to support good practice and to engage and empower students. [17] Principles have been adopted for a number of reasons. Firstly, they are derived from both the literature and evidence-based research and as such should help guide and inform good practice. Secondly, they have a broad relevance and flexibility; are neither too narrow nor too specific and are capable of implementation in many ways. As such they can be used by both students to improve and develop good practice in distributed-design information storing in a wide range of class and project activities, and by staff when designing any distributed class activity or project work. Thirdly, the principles have been defined independently with minimal overlap. This helps identify the factors impacting on distributed design information storing. Fourthly their effectiveness should be greater when more principles are operational. And finally, principles will help staff wishing to evaluate their implementation in practice through a set of measurements relating to each principle. This is currently in development.

3.1 Initial guiding Principles and Framework for d-DIS

Initially a set of 9 guiding Principles were produced from the Recommendations and Findings of the early studies and the literature in the field; see Table 2.

Table 2. 9 initial guiding Principles for d-DIS

Good practice:
1. Emphasises the need for global team project information strategy (creation of rules) early on.
2. Encourages storing of organised, comprehensive and unambiguous project information.
3. Emphasises selection and familiarisation of tool(s) before project start.
4. Encourages a team awareness of where information is stored.
5. Requires establishing what information content to store and how much.
6. Requires establishing what information types (media) to store.
7. Encourages storing of informal information to add richness and understanding.
8. Encourages regular storing of project information throughout project by both sides of distributed team.
9. Encourages reflection and interaction with stored information.

These can be mapped to a Framework; see Figure 1. Principles 1 & 3 emphasise the creation of rules and familiarisation with chosen tools, before project start. Principles 5, 6 & 7 indicate the need for an information-centered core to project work which includes both formal information of appropriate content and media type, and informal information to add richness and understanding. Author's previous work defines this core as a Project Memory [11]. The concept of project memories has been around for the last decade or so and a project memory and *"....can be defined as lessons and experiences from projects, or as project definition, activities, history and results. It should be a living and active store not static."*[15] It provides a central repository and access point for documents, supporting collaboration and communication. The circular arrows around the Project Memory indicate that Principles 2, 4, 8 & 9 should be continually applied throughout the project at all stages. Information should be organised, comprehensive and unambiguous. It should be stored regularly by all team members who know where to store information and subsequently are aware of where to find project information. And most importantly it should be reflected upon and interacted with throughout the project rather than at key stages or simply at the end. Schon [18] identifies the importance of reflection for those working in professional practice; and Kolb [19] shows that learning can be enhanced when it is organised around cycles of learning activity and reflection.

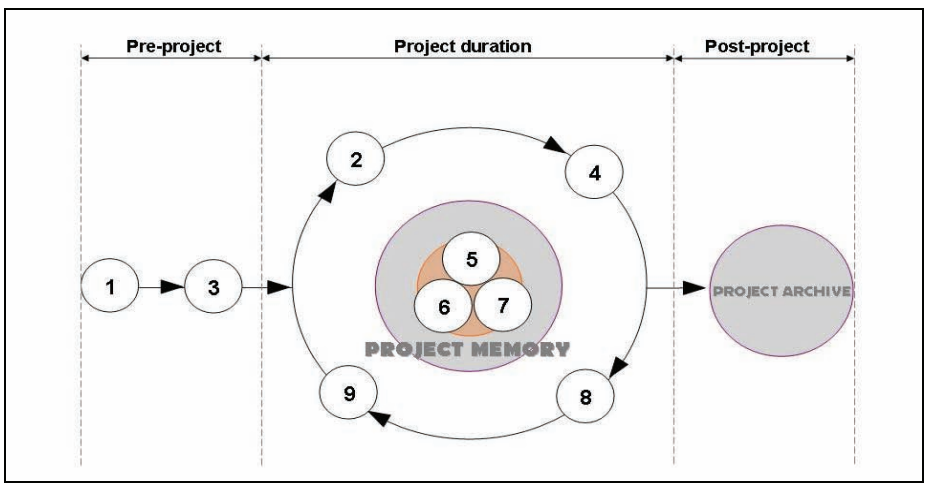

Figure 1. Initial distributed-Design Information Storing (d-DIS) Framework

The initial 9 guiding Principles were presented to students in focus groups and based on the feedback, minor revisions made, (Principles 5 & 6 were merged; some were reordered and a new Principle on recording a comprehensive 'story' was added), before presenting to staff for their feedback.

4 DETAILED FEEDBACK ON INITIAL GUIDING PRINCIPLES AND FRAMEWORK FROM STUDENTS AND STAFF

Feedback on the initial guiding Principles and Framework was sought first from students through 2 workshop-style focus groups. Each focus group lasted 75 minutes and involved 17 postgraduate Global Innovation Management students and 5th year Product Design Engineering students taking the Global Design Class 2008-2009 at DMEM, (9 in one group; 8 in the other). Students were presented with the Principles and Framework; gave feedback on each Principle; commented on gaps; and gave their thoughts on the Framework; followed by an open discussion, prompted by semi-structured questions. Minor revisions were made to the Principles, based on student feedback, and then they were presented to 8 academics and researchers, in two further focus groups. Staff feedback lasted approximately 100 minutes and took the same format as the student groups.

4.1 Student Feedback on guiding Principles

Individually, students were asked to agree or disagree with each principle, giving reasons. All students were in agreement with Principles 1 & 2 (creation of rules and need for organised and unambiguous information). The majority of students were in agreement with Principles 3 (tool selection and familiarisation), 4 (team information awareness) & 8 (regular storing). They noted that without a strategy for storing and sharing information, that information could be lost, duplicated, or be inappropriate or untimely. Time could be wasted; quality of project information could be affected; resulting in a lack of project direction, confusion and disagreement. Organised information helps give a clear understanding of complete scope of project and reduces misinterpretation. *"Chaotic storage makes expensive, time-consuming (if not impossible) the information retrieval."* Two students did not agree the need to be familiar with the technologies as they felt learning to use a tool was not uncommon in industry. One student pointed out that although it was good practice to have all team members knowing where project information was, this again wasn't always adhered to. All were in agreement that regular storing can impact on team cohesion -*"Demoralised if the other side only makes sporadic contributions."* There was also the suggestion that storing information regularly could encourage storing of redundant information which was not desirable.

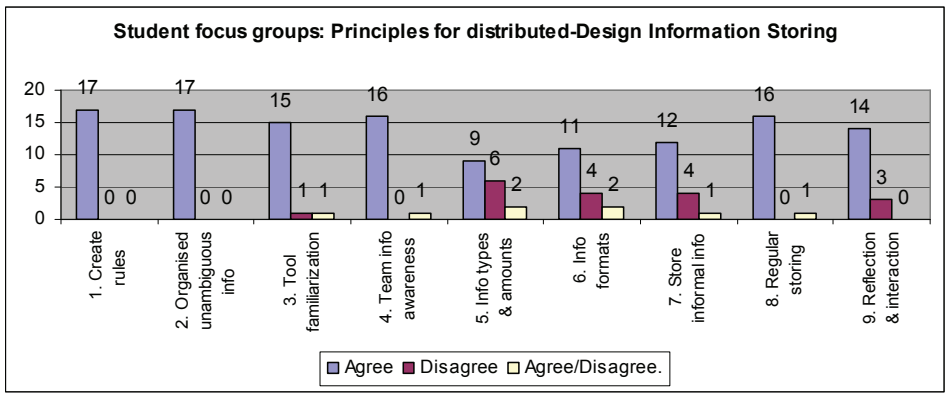

Figure 2. Numbers of students agreeing/disagreeing with guiding Principles

Principles 5, 6, 7 and 9 afforded most variance and discussion. The fewest number of students agreed with Principle 5: what information to store and how much, (9 students from 17). They felt that too much information contributed to loss of focus; storing unnecessary information wasted time; documents were often not returned to. One student noted: *"Managing information includes disposal of information"*. Disagreeing students believed that restrictions on what to store would result in limitations, e.g. loss of ideas, loss of information which could help project in later stages. Several students noted that storage space was inexpensive and that amount of information stored was only limited by size of storage space. This however, does not promote good information management practice and storing everything contributes to the issues associated with distributed design information storing. Clearly students required guidance on what to store and how much. 6 students from 17 did not

agree with Principle 6, although there was misinterpretation of the terminology here - '*formats*' being taken to mean '*file formats*' rather than '*media type*'. Of those who took 'formats' to mean 'file formats', consensus was that compatibility issues would be reduced by establishing what information formats to use. There was also agreement that all useful information should be capable of being stored and that some systems currently prevent this. A few students found Principles 5 & 6 very similar and suggested these be merged. There was also some disagreement with Principle 7 (5 students from 17) on storing informal information. In support, students noted that getting to know team members was crucial for good collaboration and informal information contributed to this. Informal processes are inherently part of the design process and [storing of informal information] cannot be excluded from a distributed task. Students reported they often found informal information hard to articulate and preferred to have face-to-face interaction to understand context better. This is often not possible in distributed situations. There also seemed to be some concern about keeping information 'professional' and that informal information was perceived to clutter storage space. Majority of participants (14 of 17) agreed with Principle 9, reporting that interaction with information keeps them updated; helps them visualise what others in team are doing and creates a feeling of collaboration. However there was the admittance that stored documents are often only viewed once and then forgotten about.
Students suggested a number of gaps to the principles, e.g. privacy of information; times for reflection and feedback; integration with communication tools; distributed design making support; definition of informal information. Additionally they offered up good practice, e.g. requirement for versioning; storing of profile information to increase team cohesion; simplicity of use; summary descriptions of information; use of keywords; and, use of file naming conventions. All of which could be included under further guidance to each principle.

4.2 Staff Feedback on guiding Principles

Like the students, all staff were in agreement with having an information strategy and creating rules. They noted that without these things could become very chaotic and this would certainly be compounded in a distributed design situation. They also felt that any strategy should be capable of being amended and flexible to some extent, during a project. All staff unanimously agreed with the storing of appropriate content, media types and amount of information, but felt that students would find it hard to define what was '*appropriate*' and hard to determine how much to store. Guidance in addition to the Principles, should be given to students as staff experience showed that students *"often stored information which was irrelevant, or not enough of the right information"*. They also all agreed to Principle 7, the storing of informal information to add richness and understanding. One researcher noted that formal information was not sufficient for accurate records and that the meaning of information could be lost if informal information was not stored.
Staff strongly supported principles on team awareness of where information lies; interaction and reflection; and the new principle on recording a comprehensive picture of the project. If everyone was aware of where information was, then they were more likely to use the same information, avoiding confusion and inconsistent decisions based on different information. Staff reported that reflection was essential. The project record/archive was seen as a mechanism for informing what could be done better next time, and important for future learning, in terms of improving information storage and project performance. From experience academics noted getting students to reflect was difficult but desirable. One academic suggested that more guidance was needed to advise students on what information and how much would constitute *a comprehensive picture*, as students found this difficult to evaluate.
Most staff agreed (6 of 8) that students should select tools to store information and know how to use them prior to project start. One academic noted that information literacy literature supports this principle. However, a few academics, didn't agree that the team had to know how to use the technologies before project start, as learning technologies *'on the job'* was not uncommon, particularly in industry. Staff felt that there should be a core of tools to allow for flexibility and adaptability, and not to hamper creativity, with the ability for others to be added later if required.
Staff views on *regular* storing were mixed - 4 members of staff agreed; 1 disagreed and 3 agreed/disagreed. Those that agreed noted that for effective shared information storage all the team members must contribute throughout the project; modifying their usual behavior if needed. This would help avoid information loss. The greatest disagreement was over the term '*regular'*. Patterns of activity evolve naturally during project work and enforcing a *regular* storing of information could interfere with this and possibly hamper creativity on a project.

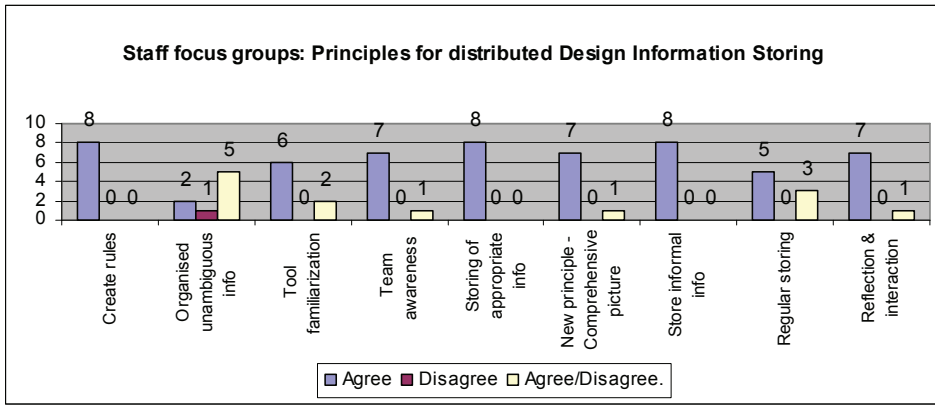

Figure 3. Numbers of staff agreeing/disagreeing with guiding Principles

They debated that, rather than information being stored *regularly*, it should be stored *consistently*, e.g. when it has a significant addition to justify any further work that may entail. Staff recognised the importance of structured and organised information, however, most felt the use of the term '*unambiguous*' caused problems. One member of staff disagreed with the principle, recognising that design project information is often ambiguous and uncertain, and it should be recorded in its original form; but that it should be presented in such a way that the information user is aware of these factors. Ambiguous information should be stored in an organised or structured manner to allow easy retrieval. It was felt that rather than the word *unambiguous* that *clarity* be used in subsequent principles.

Academics found fewer gaps in the initial proposed principles. These included the need for flexibility to be built into the strategy to allow for the handling of changes or problems as they arose. They suggested guidance on information capture and retrieval was missing. Terminology needed to be changed to avoid misunderstanding. One researcher also suggested that the aspect of a shared awareness of the quality or value of the information might be missing.

4.3 Student and Staff Thoughts on the Framework

In groups of three, students were asked to give feedback on the Framework on flipcharts. They reported that the numbering system should be re-ordered. Principles 2, 4, 6 & 8 were recognised as being continuous throughout the project. They found Principles 5 & 6 very similar and suggested they be merged. Much more guidance and advice was needed to support Principle 5. There was also a desire for a representation on the Framework of the distinction between storing of formal and informal information; along with the need to link these types of information.

Staff gave this feedback in pairs. It was suggested that the project archive could assist with future projects and an arrow was drawn from the archive back to the project-duration stage. Some felt the principles should have no order as they were unique and independent and need not be followed sequentially. Another researcher noted that the Information Storing Framework made good sense of the Principles and the Framework should be positioned within the Information Life Cycle, thus building on others' existing work.

4.4 Staff and Student Comments in Open Discussion

During open student discussion there was consensus that the Principles were very useful but perhaps too general. More specific advice was needed and it was suggested by both focus groups that their relevance in practice be made explicit through the use of examples, in particular what might happen if good practice principles were not applied. It was suggested that they could be used to help tool/technologies selection. Students felt that the principles should become part of class/project design, and that staff place emphasis on them when teaching. They would need time pre-project to apply the principles. One student suggested a form of checklist for good distributed information storing practice. They felt this would encourage reviewing and reflection throughout the project. Other students felt it best to introduce the principles at the beginning of the project in a seminar or at stages throughout the project. Quality of information was important to students, *"…it's not good to store huge amounts of*

information that nobody is going to go back to …that is like completely useless…to know that it will be important in the future, and it's got a purpose." They reported that lack of time was a key factor contributing to poor distributed information management. It would be beneficial to spend more time on pre-project planning; *"…instead of fumbling along and…actually it would have saved us our efforts and time…"* Supporting this, they noted Principles 1 & 3 as the most important - the need for a project information strategy and familiarisation with tool(s).

There was variation across students' thoughts on what and how much information should be stored, with some students feeling it was counterproductive to store all information: *"…unnecessary and also a lot of work."* They regarded formal information to be an output and informal information to be the rationale behind its generation. Several felt that only key information should be stored; formal information to support the project objectives. Some felt that some informal information should be stored; not focused on too much; but reflected on from time to time. Informal information was perceived as long and messy, 'cluttering up' the system. Others felt that all information was vital, although this took time to store. There was recognition of the need and value of informal information for reflection but students couldn't agree on how much to store, and disappointingly still a few students who didn't see the benefits of reflection at all. Several students discussed the option of storing formal and informal information in different places but having a link between them.

In general staff felt the principles would be useful to students; something students could implement in project work and also be of use to academics in class design. They felt the principles should be kept broad and not be too specific so they could be used in different classes and even disciplines. A number of academics reiterated that students would find it difficult to interpret the principles and apply them in their project work in reality, without further additional supporting guidance. In order to make the principles more acceptable by students certain terminology would have to be changed to avoid misunderstanding, e.g. *formats, regular, unambiguous, richness*. And finally, they thought they would improve performance; they would provide a structure in themselves; and they could be seen as a kick-off to project work. In terms of implementing the principles in the class academics and researchers agreed with the students' suggestions for previous examples of storing, good and bad; a checklist of storing guidelines throughout project; and more time given to project planning. In particular, academics felt it was important to get students to reflect on the storing of structured information.

5 REFINEMENT OF PRINCIPLES AND FRAMEWORK

The Framework and the Principles were then refined, see Figures 4 & 5, based directly on the feedback sessions and also with reference to current work of others in this area, in particular, developmental work on a set of Principles of Engineering Information Management from the Knowledge and Information Management (KIM) Grand Challenge Project [20].

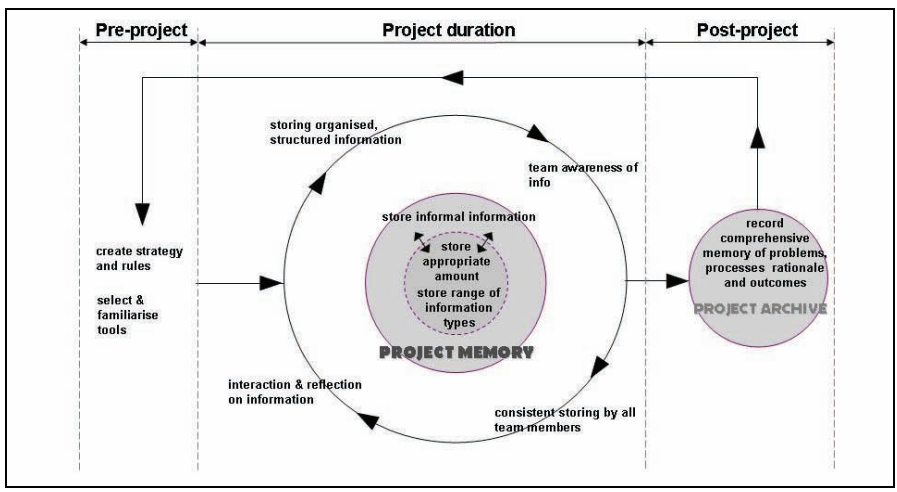

Figure 4. refined distributed-Design Information Storing (d-DIS) Framework

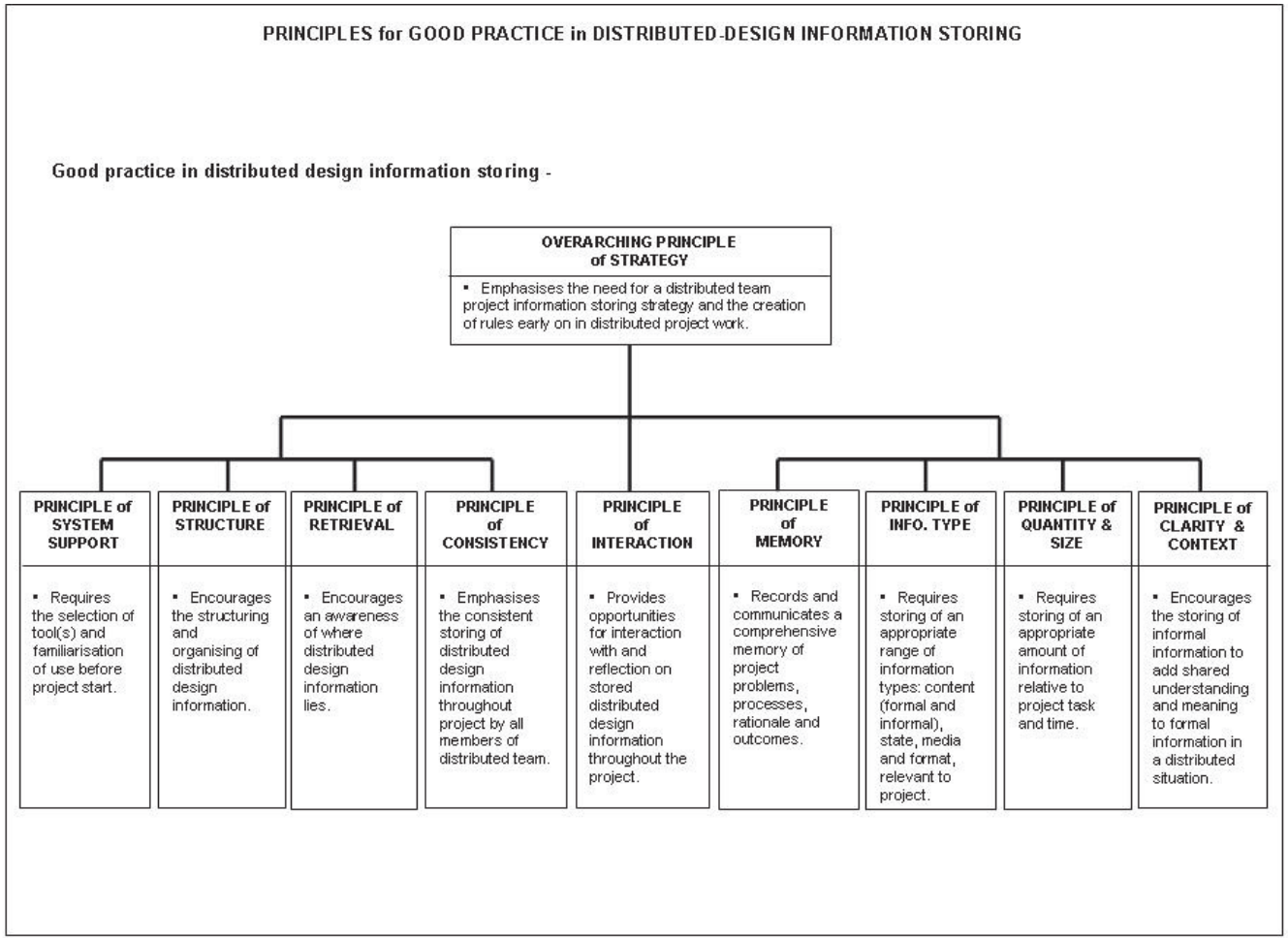

Figure 5. Refined Principles for distributed-Design Information Storing

Feedback has been incorporated for a better understanding of the principles; they are no longer numbered; their positioning on the Framework has been adjusted and the principles have each been given unique names for easy identification: Principle of System Support, Structure, Retrieval, Consistency, Interaction (and Reflection), Memory, Information Type, Quantity & Size, Clarity & Context. This helps to give the principles independence with minimal overlap. Adoption of these key principles, designed to improve good practice, would help to satisfy the Overarching Principle of Strategy - the need for a distributed team project information storing strategy.
Additional guidance for each of the principles is now being written to further support students and staff. Full presentation of the refined Principles, their explanations and guidances cannot be included here, due to space, but are the content for a future paper.

6 CONCLUSIONS AND FUTURE WORK

From the studies on how students stored information in distributed-design project work and the focus groups it was evident that students require guidance on how to store information in a distributed situation. Findings of the studies and the literature, underpinned the development a set of initial guiding Principles to support good practice in distributed-design information storing. Feedback was positive: students and staff felt their implementation would be very useful. They would help reduce the frustration and confusion often associated with distributed project work, e.g. lost and incomplete information, lack of context, poor communication, unable to find information, lack of team trust, etc. Students reported that implementing the Principles would certainly save time; support better collaboration and help them to manage and share project resources better; all allowing them to focus more on the design challenge. They expressed a need to have examples to understand the importance of the guidelines and their relevance; especially for those not having previously experienced distributed design working. More specific guidance was also required, e.g. on what to store and how much. Staff were in favour of the use of the Principles as their implementation would provide a valuable archive which could support project reflection and offer opportunities for learning. Additionally their implementation would promote good practice in distributed-design information storing and better prepare students for industry and employment in the global market.
Refinement of the Principles for good practice in distributed-design information storing is ongoing, and now the main focus of work is on developing a method of measuring the success of their impact in terms of improving the management of distributed project resources, project outcomes and student satisfaction with project processes. Further work will also explore how the Principles can be used in classes by the students and how practical examples from the case studies can be collated and presented. Use of the Principles in student classes will be trialed in distributed project work in the Global Design Class, at DMEM, Strathclyde University, in academic session 2009-2010.

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