CSCW in Industry and Education: Transferring Knowledge in Engineering Design

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Abstract

This paper describes the findings of three recently completed research programs conducted at the University of Strathclyde. Each of the projects involves the implementation and usage of Computer Supported Co-operative Working (CSCW) technology within the design process. Two of the projects described are education based whilst the other was conducted in collaboration with industry based on live industrial projects. The paper presents the findings of each of the projects and then explores opportunities for cross-sectoral lessons.

1 Introduction and background

In recent years, extensive research and experimentation has been conducted in the use of Computer Supported Collaborative Working (CSCW) tools within both the industrial and educational arena [1-8, 9-14]. Opportunities exist for lessons to be learned through the identification of similarities and differences in the findings of such research. Allowing, recognition of generic findings and possible transferable lessons.

This paper presents the findings of three recent research projects carried out at the University of Strathclyde. Two of the projects, ICON [9, 12] & ICON2 [10, 11, 12] investigated the usage of CSCW tools by disparate engineering design students. Whilst, a Design Council funded research project investigated the introduction and usage of shared workspace technology within the design process of three companies and their supply chain [16,17].

This paper presents an overview of the approach and findings of the ICON and the Design Council funded "Integration of Design Specialists Through Shared Workspaces" projects. This is followed by a comparative reflection of the results allowing identification of generic findings together with opportunities for cross-sectoral lessons.

2 ICON

2.1 The ICON concept

ICON (Institutional Collaboration Over Networks) began in June 1997 with a week-long collaborative design project involving four pairs of students. The students came from the Product Design Engineering course at Strathclyde University and the same course run jointly at Glasgow School of Art/Glasgow University. The students tackled different design briefs and were asked to provide a solution and present their findings at the end of the week. They were restricted to the use of network technologies such as audio/video conferencing and chat tools and were prohibited to communicate by any other means. Although difficulties were encountered through the week, the project was considered a success in that it proved virtual collaborative design projects were feasible. The difficulties encountered were also examined and resultant changes made to the system for the second project, ICON2, which ran for eight days in September 1998. This iterative process, illustrated in figure 1, resulted in modifications being made to the system in terms of the methodological approach and project organisation, in the pursuit of ensuring future success. By identifying the barriers to effective communication and work, benefits of adopting CSCW in a design context can be maximised and remedial strategies and guidelines can be developed for implementation by the design community.

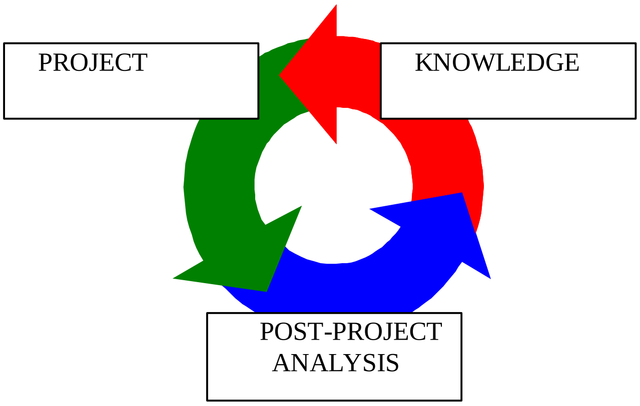

Figure 1 - Iterative development process

The underlying philosophy to the ICON projects involved improving the accessibility CSCW tools in order that policy makers in academia could implement similar projects easily, efficiently and with as little as possible start up. This included using as much freeware as possible and avoidance of ISDN.

The main objectives of the ICON projects can be outlined as follows:

- To ascertain the practicality of facilitating Internet based remote collaborative design projects for students;

- To introduce students to remote design environments and technology currently being adopted in industry and further, to investigate any obstacles encountered in implementing and utilising this technology in design education;

- To investigate the impact of the technology on the effective teaching and practice of the design process;

- To study the ability of the technology to overcome cultural differences between the participating institutions and to generally promote inter-institutional collaboration;

- To encourage diversified learning. The product design engineering degrees taught by each of the participating departments incorporate many common elements, however each of these departments presents its course from a different pedagogical perspective. ICON aimed to encourage the students to share their knowledge base in an attempt to widen both their individual and institutional skill sets.

2.2 Methodology

In the six weeks prior to the first ICON project three briefing sessions were arranged to introduce students to the project methodology, the technology and participating staff and students. Evaluation of the project took place through the implementation of pre/post project questionnaires and interviews, project diaries and video recordings of the final presentations.

The design interface for the project came in the form of a project website incorporating design briefs, project schedules and technical support. The briefs, which were disclosed on the morning of the first project day varied for each team and were allocated randomly. The briefs were

- Design a portable electronic scanner/sketch aid/notetaker for students

- Design a powered weeding device for the 60+ market

- Design a portable facial hair remover

- Design a hot frothy chocolate machine

True to the ICON philosophy participating students were restricted to using the tools and technologies made available to them. The computers used for ICON were cross platform PC/Mac, due to the existing facilities at each institution. CuSeeMe provided a single video link between the institutions with audio conferencing being provided for all teams. Microsoft office, BSCW (Basic Support for Co-operative Work), Netscape Navigator, Paintshop Pro, Adobe Photoshop, AutoCAD, and Peoplesize were provided to aid the completion of the briefs.

2.3 Findings

In general, the first ICON project was a success. Although technical difficulties were encountered throughout the week the students enjoyed the experience and reported a significant improvement in their computer competence. The students were content with the project, mainly due to low levels of expectation. Despite the positivity participants did not envisage such methods of working as constituting a replacement for conventional practices. Perceptions and levels of expectation were found to be central to the success of implementing such projects and this aspect will be discussed later in the paper.

Participating students made good use of the tools, BSCW being the most successful. The use of audio was found to be a critical factor in effective communication, concurring with other research [13].

The following guidelines were distilled from the first ICON project. These were used as the basis for designing the system for ICON2 project,

- Agree on the technologies in advance and ensure that they can be used at each site;

- Wherever possible, standardise the hardware and software. Many difficulties were experienced in this project because communications technologies had to be cross platform i.e. PC & Mac;

- Allow enough time to set up and test the technologies. Attention to details such as student shared workspace registration and configuring email addresses on machines to be used for the project may also be necessary;

- Provide a variety of technologies so that if one communication channel fails another may be adopted;

- Allow students time to familiarise themselves with the technology before the project commences;

- Ensure staff with the necessary expertise are available to assist students having technical problems;

- Be realistic about what can be achieved. Eight students, four from each institution, was considered a manageable size for this project.

3 ICON2

3.1 ICON2

Similar to ICON, ICON2 involved the partnership of four pairs of students from each academic institution. Three teams were restricted to the use of network technologies to complete the brief whilst, a control team was also nominated who could meet as they wished and were allowed to use any means of communication with the notable exception of audio and video conferencing. The project lasted for eight days and was split into two main phases. Phase 1 comprised a sacrificial project that allowed the students to get used to the technology at the same time as conducting research for phase 2. The required deliverables from this part of the project comprised a Product Design Specification and a Theme Board. Phase 2 started with the participating students being presented with a design brief. This was as follows:

A portable syringe driver is the "Walkman" of the medical services industry. The small, now pocket-sized devices are connected by a thin flexible tube to an intravenous cannula in the patient. The objective of the project is to investigate and propose a new visually, ergonomically and technically advanced appropriate design which meets the complex procedural medical, clinical user and patient demands of such a product.

Each team was to develop a product to meet the brief and to present their chosen concept using a CAD produced product layout drawing together with a rendered presentation graphic. The Clyde Virtual Design Studio (CVDS) [14], which was developed in the wake of ICON, was used as the basis for tackling the brief. The CVDS integrated the set of tools/facilities that were required for the successful completion of the project. The CVDS consists of four main components:

Data management - *storage space for project work:* In the form of BSCW which was downloaded free from the Internet and configured for use with the CVDS.

Communications suite - *local audio, video, chat and whiteboard facilities:* Microsoft Net Meeting, Netscape Communicator and Ewgie chat were provided.

Local applications - *relevant software programs:* AutoCAD R13, 3D Studio MAX, Microsoft Office, Paintshop Pro, Adobe Photoshop and PeopleSize were provided.

Reference area - *General and project specific links and information.*

As with the first ICON project an effort was made to record as much information as possible. For ICON2 the following methods were employed:

- Daily project videos;
- Pre/post project questionnaires
- Support staff logs
- On-line diaries
- One to one post project interviews
- Presentation video

3.2 Findings

The main findings on ICON2 can be classified in the following areas:

- System and tool usage
- Benefits
- Barriers

System and tool usage

There is much debate with regards to the effectiveness of synchronous V's asynchronous working practices [2, 6 & 9]. The overall split for all the teams in ICON2 was 68% asynchronous V's 32% synchronous. This level of synchronous work is relatively and may be attributed to the fact that the project was of short duration and that the students didn't know one another personally. Therefore, a high level of synchronous work was required in order to ensure the design was moving in the right direction, especially with tight deadlines looming. Other factors may include the ability of the tools to facilitate synchronous communication and the perseverance of the students, an attitude that was, perhaps, expected of them.

Each of the three networked teams displayed very different patterns in communicating. Figure 2 shows how team 3 collaborated over the course of the project.

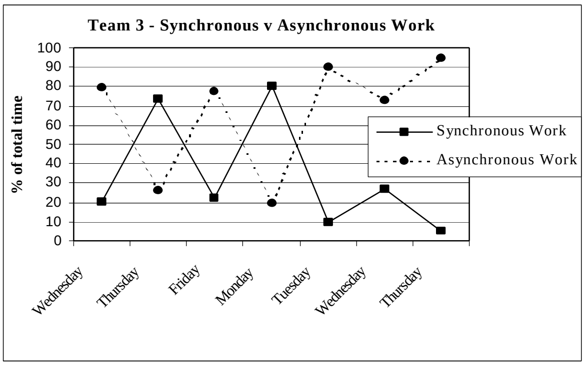

Figure 2 team 3 daily synchronous/asynchronous split

Work Modes and Habits

From examination of the personal log and on-line diaries it became apparent that the participants generally, displayed the same work mode at each of the various stages. By examining this it may be possible to maximise benefits and ease teething trouble in future projects. To this end, figure 4 is proposed. This figure is basically a summary of the work practices and attitudes of the ICON2 participants. The students picked up the technology relatively quickly and used only what they found useful after a while. Other results included a decrease in the need for technical support although most students agreed that constant support would always be welcomed. One aspect of the model that could be improved is the participants' tendency to become less tolerant as the project goes on. As one evaluator mentioned, " . . . *the more it goes well, the more annoying it is when the odd thing goes wrong."* These frustrations can be attributed, partly, to the tight time-scale of the project.

Stage	Induction	Familiarisation	Expert
Attitude	Keen	Content	Frustrated/ Stressed
Tools Usage	Using a wide variety	Narrowing usage	Whatever appropriate to deliverables
Attitude to tools	*"open to anything"*	*"open to what works"*	*"nothing works"*
Level of back-up	Tools instruction needed	Software support only	Moderate software support

Less Tolerance

Time

Figure 3 work-modes and attitudes during Icon2

Additional training and experience of using such a system should result in minimal frustrations and less detraction from the design process. We may not be able to change the fact that participants become less tolerant as the project progresses (this may not be a bad thing, participants will not settle for mediocre performance) but if we can manage the project effectively this may not matter as much. Additionally, other measures such as on-line tutorials may substitute the need for software support.

Benefits

The main benefits of the ICON2 project can be summarised as follows:

- A steep learning curve for the students that resulted in significant improvements in their computer skill and confidence levels;

- Greater experience and knowledge for staff for eventual input into a new system design;

• Widening of scope of students knowledge and experience through working with students from another institution;

• Strengthening of inter-institutional links;

• Student perception of certain elements of the design process being improved through practical project;

Barriers

The barriers encountered in ICON2 can be categorised as:

• Technology
• Educational Issues
• Social/Cultural
• Project Management
• Psychological/physiological

For a detailed discussion regarding the barriers, refer to [15].

3.3 Conclusions/recommendations

Analysis of findings allows certain guidelines to be produced for future virtual collaborative design projects.

• A project manager or champion should be appointed who should be aware of the issues and possible outputs of the project;

• Any additional input to projects should be cleared by the project manager and its effects closely considered;

• Future collaborative design projects should closely resemble conventional semester long modules so that the technology is the only differing factor in the project;

• Students should be trained adequately in all software that is to be used in project. At least an introduction to the packages should be completed;

• Participating students should be trained in adopting the correct behaviour for such projects;

• Periodic contact between colleague(s) should be encouraged to ensure working towards a common goal;

• Depending on the specifics of the teaching methodology consideration should be made to letting design partners' meet physically before and/or after the project. Working on the start of the project in person and presenting findings afterwards are options;

• Encourage high level synchronous collaboration after long periods of non-contact. In a conventional project this will usually mean the start and end of sessions and the start of important phases;

• Materials should be developed which can support the detail design phase of the design project including online specifications and design methods;

• Design briefs should be similar but not identical to encourage the correct levels of inter-institutional and collocated collaboration;

• On site support at participating institutions is advised for the start of any project until students become familiar with technology;

• Software support should be considered for stages of the project when students are required to produce an output. Online support is an option;

• Adequate space should be provided for students to carry out other activities at their workstation, such as sketching and writing;

• An awareness of stages of behaviour in project participants should be evident in support staff;

• An awareness of possible effects of different personalities and how to respond is also advised;

• Students should take appropriate exercise to combat any physiological problems associated with long periods in front of a computer;

Another important need for such projects is that of *setting up* future projects, ensuring that any preparation is completed as economically and effectively as possible. The following stages have been identified:

IDENTIFICATION - *methodology, resources*
INSTALLATION - *technology*
PREPARATION - *briefs, students*
RUNNING & MONITORING - *support*
EVALUATION - *input to next iteration*

4 Integration of design specialists through shared workspaces

4.1 Introduction and background

This recently completed research, funded by the UK Design Council, investigated the introduction and usage of shared workspace technology within the design process of a number of small and medium sized enterprises (SME's).

Within the context of this paper the term shared workspace, has been used to describe a computer based collaborative working system typically consisting of the following functionality:
video and data conferencing ;
real time application sharing ;
shared whiteboards;
file transfer.

Development and use of such technology to date has been dominated by large multinational companies. Ford, for example, have used the latest collaborative technologies to allow their seven design centres, each of which specialises in different aspects of design, to communicate effectively across great distances and different time zones. Benefits demonstrated by such projects include:

- improvements in the flow of work allows companies to move and react faster;
- product development lead time and costs are reduced while maintaining or improving quality;
- time to market is reduced
- relationships and efficiency of communications throughout the supply chain.

It is clear that current desktop data and video conferencing technology offers the possibility for companies to collaborate effectively and at relatively low cost over Networks using personal computers. Furthermore, the benefits that collaborative working technologies can bring to the new product development process are apparent. However, their widespread use has been restricted by a number of organisational and technological issues. The main aim of this research is to address the key issues relating to the implementation and adoption of these technologies within companies and their supply chain.

4.2 Project approach

The research approach adopted is best described as a series of industrial case studies involving a number of companies from a range of industries specifically Product Design, Construction and Electronics Manufacture.

The general methodology adopted within each of the companies was to run successive case studies each building upon and testing the findings of the previous. Therefore, each case study followed a different methodology focusing on slightly different aspects. The first company case study commenced in May 1997 with a series of trials being carried out in Hulley & Kirkwood a mechanical and electrical building services consultancy. This was followed by a product design company, Devpro starting in December 1997. Finally, the Keltek electronics case study began in June 1998.

A variety of data collection methods each aimed at capturing specific types of information were devised and employed during the case studies specifically:

- Initial Structured Interview
- Post Demonstration Questionnaire
- Diary of Observations:
- On-Line Logging System
- Weekly Questionnaires:
- Final Interview.

4.3 Findings

The results of this research can be classified within the following areas:

- Barriers to the introduction and usage of the shared workspace;
- Typical system usage;
- Benefits obtained through system usage;
- Perceptions of the company throughout the introduction and usage of the shared workspace;

Barriers to the introduction and use of shared workspaces

Barriers identified during the introduction and use of the shared workspace can be classified under the following main areas:

- Management;
- Psychological / Perceptions;
- Technology Related;

- Training.

A full description of each of the barriers identified is provided in [16]

Benefits of shared workspace usage

The main benefits achieved within the case study companies can be summarised as:

- Reduction in the time taken to carry out a variety of design activities due to less re-work, ambiguity, file transferring and paper chasing;

- Improved design quality;

- The companies design costs are reduced therefore, reducing the cost of the services to their clients giving them a market advantage over their competitors;

- Due to improved communication clients invest less time on design, reducing their costs further;

- Companies adopting the technology feel they are getting a better response from remote parties using the shared workspace than they would get adopting a conventional communication tools.

Typical system usage

In general, the shared workspace technology was not used to replace travel. Despite the fact that prior to the introduction of the technology companies felt one of the greatest benefits they would achieve would be a reduction in frequency of travel and savings relating to this. In reality, there were certain activities that each of the companies felt could not be carried out remotely therefore, the reduction in travel and related costs was found to be negligible. Typically, the system was used to enhance design activities that were previously carried out using conventional asynchronous communication media such as the application of e-mail, telephone, fax etc. to carry out the following activities:

- introducing and discussing design changes;
- clarifying design details;
- presenting designs to clients for approval;
- discussing project progress.

The shared workspace was used differently in each of the participating companies. Hulley and Kirkwood initially found it difficult to co-ordinate times for synchronous use of the system. After a few months of barely using the system they devised a method of employing the system in an asynchronous manner, which was found to be advantageous. In contrast, Keltek adopted the shared workspace in a synchronous manner from commencement of usage. The main difference between the companies being that the key system users in Keltek were predominantly located at their desk whilst, the key system users adopting the system asynchronously spent a considerable percentage of their time out of the office.

For synchronous use application sharing was found to be the most useful tool, being employed almost 100% of the time. On the other hand, Hulley and Kirkwood who adopted an asynchronous mode of working found the whiteboard to be an extremely useful tool employing it more than 90% of the time. Usage of the shared workspace went through ‘cycles’ i.e. short periods when it was used synchronously almost on a daily basis followed directly by longer periods when it may not be used for several months whilst designers work alone of with co-located team members.

Company perceptions

Company perceptions changed dramatically throughout the project. Initially, prior to the introduction of the technology all of the companies were enthusiastic at the prospect of using the shared workspace. Initial impressions were that the shared workspace would have a positive impact on communication between remote design team members. Preconceived benefits include:

- Reduced travel, savings in flight tickets and a reduction in the time spent travelling;
- Improved communication within the distributed design team;
- Closer working relationships within the company and their supply chain;
- Better quality products;
- Reduction in the time taken to execute interactive processes, fewer redesigns.

A minority of prospective system users had reservations about using the shared workspace instigated by concerns that their IT skills may not be adequate.

Once the system was introduced in each of the companies initial enthusiasm was thwarted by a number of barriers, primarily relating to:

- The location of the shared workspace;
- Confidence in using the system;
- Technical issues;
- Fire fighting.

Although over 90% of prospective system users had initially, expressed an enthusiastic interest in using the shared workspace when the system was installed less than five percent of them retained this enthusiasm. In instances where individuals overcame initial barriers and used the system to their advantage it was found that initial enthusiasm returned. The companies who adopted the system within their design process have either purchased addition systems or have made plans to do so in the near future.

Guidelines

The main output of this research was the development of guidelines for the effective introduction and usage of the shared workspaces within the design process. These guidelines follow four basic stages:

Recognition of need
Preparation
Introduction
Adoption

Recognition of need:

Identify need to improve communication;

Investigate means of improving communication;

Identify shared workspaces as solution;

Ensure the information regarding the cost of shared workspace technology is factual;

Ensure that the remote parties with which your company frequently communicates with have compatible software;

Preparation:

Select and appoint a committed shared workspace champion;

Ensure IT staff are involved as early as possible and that sufficient time is set aside in their schedule for system installation;

Review information sharing requirements;

Specify hardware and software;

Any future plans for changing operating system should be considered when purchasing the shared workspace system;

Review information current information sharing practice;

Identify key system users;

Procure equipment - one shared workspace should be purchased for each key system user;

Review current network infrastructure and arrange update where necessary to ensure seamless access to the network for each key system user;

Set-up and test equipment;

The shared workspace should be located where the key system user has readily available access, preferably it should be installed on the PC of the key system users PCs';

Set up should ensure the system on which the shared workspace is installed mirrors standard company set up;

Ensure audio is of a high standard;

Ensure sufficient RAM is available to support the shared workspace software and the operation of additional software;

Plan training:

Proper training is essential as many prospective system users perceive the shared workspace to be difficult to use and as a result are reluctant to use it. Effective training will help overcome this;

System users should be trained both to set-up and use the system properly as lack of knowledge and inexperience in usage and setting up can lead to crashing which in turn can result in lack of confidence amongst system users;

Introduction:

Identify pilot project and key system users;

Initially, until confidence is gained, the shared workspace should be used on projects which are not on the critical path;

Use system within pilot project;

Until users become familiar and confident system users the local video window should be made small or completely invisible as many people find looking at their own image extremely off putting;

Adoption:

Extend use;

Monitor benefits;

Develop infrastructure;

Train new staff.

5 Comparative findings and conclusions

5.1 Common areas

Through comparing the findings for the educational and industrial projects described in this paper it is clear there are areas of similarity between the project findings. These are discussed in the following paragraphs.

Barriers: the majority of barriers identified in both projects can clearly be classified under common headings, specifically:

Technology;
Social/ cultural;
Management;
Psychological/physiological;
Training.

Usage:

• In both the educational and industrial based projects it was found that the technology was employed in different ways by each "team";

• Majority of communication still asynchronous despite user preconceptions that synchronous communication would increase dramatically. This finding is common to other research projects [5].

• Industrial case studies show that users go through short phases of intensive synchronous usage followed directly by longer periods of asynchronous communication. A similar pattern is apparent in the ICON2 project illustrated in figure 2;

• Both projects show that CSCW tools cannot replace face to face meetings, in their present form;

Technology:

• A lack of sufficient training/preparation can lead to a severe lack of confidence in the system and ultimately, non-use;

• Good quality audio was found to be absolutely critical in both educational and industrial usage with video taking the role of a secondary communication link. This result is common to other research findings [13];

• Both projects show that a lack of hardware / software standardisation can render the system unusable;

Management:

• As CSCW involves the collaboration of people and institutions conflicting objectives can sometimes mean that ventures fail to become reality. Both the educational and industrial projects showed that effective management is crucial to compromising on different agendas such as policy, timetabling and resources;

• A project champion is essential in both industrial and academic projects to ensure successful management of the system.

5.2 Transference of lessons between sectors

The majority of findings from both projects are common. However, both projects provide scope for lessons to be transferred from industry to education and vice versa.

Industry to Education:

• More barriers were identified in the industrial based projects, due mainly to the almost artificial "sheltered" nature of the ICON projects. These additional barriers have been developed in to guidelines which could prove useful in future educational projects;

• Industrial case studies can be used as stand alone teaching material within educational environments in order to provide students with a realistic overview of "the real world";

Education to Industry:

• Both ICON projects were well managed and prepared for well in advance of commencing. As a result, system usage was smoother than within the companies. Industrial case studies show that companies are keen to commence usage in order to achieve the perceived benefits and tend to gloss over the preparation and management stage, often to the detriment of successful technology implementation;

• In ICON2 a variety of technologies were provided to ensure a back-up was available in case of failure of other communication media. In addition, the continuous availability of technical support eased potential problems. This approach would prove beneficial in industry where key system users become very frustrated when communication technology fails, often becoming annoyed to the point where they may not use the system again ;

• The ICON projects showed that students adopted high levels of synchronous work to cope with short project deadlines. Results from industry showed key system users tended to "back off" employing technology when tight deadlines were looming often resorting to conventional asynchronous modes which are more time consuming.

• Throughout the ICON projects, particular attention was paid to the learning process that the students went through in the course of the project, both in terms of the new technology and the core material. As CSCW technologies are new to most people in education and industry, the latter can learn from the former in methods that maximise quick and efficient uptake of the new systems - all engage in the learning process.

5.3 Conclusions

It is evident from the research findings presented in this paper that lessons can be transferred between education and industry sectors. Furthermore, common guidelines can be developed in the form of procedural stages to facilitate the successful implementation and usage of CSCW technology within both arenas.

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