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Lyceum: Internet Voice Groupware for Distance Learning

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Abstract: This paper describes the design, implementation and deployment of *Lyceum*, a groupware system providing students and tutors with real time voice conferencing and visual workspace tools, over the standard internet. Lyceum uses a Java client/server architecture to tackle a formidable set of networking requirements: multi-way voice communication with synchronous shared displays, scalable to hundreds of simultaneous users, running over normal modem connections via unknown internet service providers, on home PCs. Additionally, the design had to support multiple courses with different requirements. We describe the interdisciplinary requirements analysis, and iterative design process, by which an academic course team was able to specify and evaluate prototypes. We present the system's architecture, describe the technical successes and failures from Lyceum's first large scale deployment, and summarise its affordances for interaction and learning.

Keywords: Voice over the Internet, Synchronous Collaboration, Shared Displays, Groupware, Java

1 Introduction

The Open University is a completely distance teaching institution, which since its foundation in 1969 has been experimenting with different learning media and techniques for closing the gap between distance learning students and their tutors. One of the OU's primary concerns is the development of pedagogically effective, interactive environments that augment paper (paper remaining one of the key media in 'multimedia'–the OU continues to be the UK Post Office's largest customer). Although the World Wide Web is being widely acclaimed as a medium to revolutionize distance teaching, its primary role has to date been the convenient publishing of 'digital paper', plus simple hypertext. Interactive multimedia is beginning to be delivered via Web browsers, although convincing examples of *shared, networked multimedia* are still relatively scarce.

Work on the role of the *standard* internet in education (i.e. not high bandwidth networks such as Mbone [10] or ATM [2]) has almost completely focused on asynchronous communication (e.g. [9]). In contrast, the work reported here investigates how the internet can be practically and usefully used to mediate real time communication. *Groupware* providing *synchronous representational tools* such as a whiteboard has been implementable since Doug Englebart's pioneering NLS system in the 1960s [6]. Since then, numerous researchers have studied architectural and user interface design issues in shared workspaces, e.g. [8,13,17], whilst others have tested shared audio spaces [1] and video spaces [3]. Almost all of these, however, operated over small scale and/or high bandwidth networks, e.g. [11]. Our interest, however, is in technologies that will run on widely available computers (in contrast to a tightly controlled machine, or high-end workstation), over the standard internet, accessed via a standard modem. Developments such as the Java language (enabling highly interactive, internetworked clients and servers), 'voice-on-the-net' (e.g. [18]), increasing access to the internet, and faster home PCs make synchronous groupware a practical possibility for connecting students and tutors who need to punctuate asynchronous communication with work in 'real time'. Video conferencing over current internet bandwidth does not yet meet an acceptable quality, and consumes valuable bandwidth that in our experience is better used for voice and visuals.

In this paper, we describe *Lyceum*, a synchronous collaboration environment for the standard internet. The paper is written from the perspectives of an academic (SBS) who was a member of the course team using Lyceum, and who also mediated between other academics, and developers (SM). JB and TE were tutors who assisted their peers in learning Lyceum. This paper's contributions primarily concern Lyceum's design process, technical advances, and the technical successes and failures of its first deployment. Separate papers (in preparation) report the pedagogical evaluation of Lyceum from the perspective of online students and tutors. The paper is organised as follows. In Section 2 we describe the requirements analysis and design process by which the course team was able to specify and evaluate prototypes. Section 3 introduces Lyceum's user interface, Section 4 the considerable technical challenges

faced and the system's approach to tackling these, Section 5 reports on the system's technical performance in its first large scale deployment, and Section 6 outlines some of Lyceum's primary affordances for interaction and learning.

2 Requirements analysis and design process

2.1 Background

The first course to deploy Lyceum as a mainstream technology was *B823: Managing Knowledge*, a six month MBA final year option (Nov.'99-April'00), with 70 tutors and 850 students across Europe. In 1998, a student assignment was conceived in which students would work in teams over the internet, assessing information on websites, at the same time reflecting on their own team process and the tools they were using for their collective sensemaking. This assignment was trialled initially using only asynchronous text conferencing and text chat for synchronous communication; text chat proved inadequate and exhausting for synchronous discussions. An alternative was to use phone conferencing, but this is an expensive route, and requires tedious pre-booking of conference calls with providers. The course team became interested in the potential of internet voice conferencing following ongoing trials of commercial and home-grown 'voice-on-the-net' technologies ([6]–Chapters 6+9). In early 1999, a re-run of the student assignment using a commercial voice over the net system gave very promising results. Meanwhile, very successful small scale Lyceum trials had been held during 1998-99 on several of the OU's foreign language courses, enabling students across Europe to practise their oral skills [14]. This led to the decision to experiment with Lyceum on the knowledge management course for the student assignment, and several tutorials.

2.2 Brokering between design stakeholders

Educational institutions need design processes by which academics, educational technologists, user interface designers, programmers and students can work together to create effective systems. This is a special instance of the broader requirement for user-centred, participatory design established by the human-computer interaction (HCI) community (e.g. [4,12]). A key part of this process involves people capable of bridging between communities, whom Wenger [19] has termed 'brokers', individuals who can 'patrol' the boundary between two communities of practice, able to operate in both 'worlds.'

For B823's use of Lyceum, the stakeholders were the academic course team within the OU Business School, including the first author who is also an HCI researcher/designer, a team of experienced tutors who were brought in to assist in the design of tutorial resources, two specialist tutors (TE and JB) who became Lyceum specialists to help other tutors, the tutor community itself, the students, the software developers and Helpdesk team, and a variety of regional staff responsible for assigning students to tutor groups. Brokering between communities thus took a variety of forms, critically:

- The academic/HCI designer was able to advise the course team in their deliberations about how to use Lyceum, translate their visions into functional and user interface requirements, and liaise with the Lyceum project manager, along with many meetings between the project manager and tutorial working group (see 2.3).
- The Tutor/Lyceum-specialists had the advantage of being recognised members of the tutorial community, who understood their concerns, and assisted them in getting to grips with the new medium. In the period prior to the course's start, and during the course's presentation, they ran regular practice sessions so that other tutors knew there would be people online to talk with, and structured activities or discussion themes relevant to the course (e.g. 'ideas for running tutorial 2').

Despite these efforts, we note later how some of the stakeholders were excluded in the design process.

During 1999, Lyceum prototypes underwent several rounds of testing, first by the course team and selected tutors working on tutorial materials, and then by a larger subset of tutors. The functionality and interfaces for the three workspace tools (Figures 1-4 below) were defined from use scenarios of the two specific applications that the course anticipated for Lyceum, namely for the student team assignment, and for holding tutorials.

2.3 Tutor resources

Voice conferencing groupware is a new medium for tutors and students alike. We were required to train the tutors to use Lyceum to deliver four online tutorials (about a dozen students/group) in place of face-to-face tutorials (although in fact some of these tutorials were held face-face in the end due to technical difficulties). This required intensive work to prepare tutorial resources designed for the new medium, and online training sessions to give tutors hands-on experience and awareness of the process skills required to use the medium effectively. A tutorial working group was formed comprising academic, tutoring and HCI design expertise. Over several months, materials were prototyped in Lyceum to test intuitions about the effective structuring of tutorials. A resource pack was provided (paper and electronic) for each tutorial, setting out the goals, a plan for the sessions (ranging from a single hour to several sessions), visual aids, and discussion topics for pre-Lyceum asynchronous conferences and for the tutorial itself. In conventional tutorials it is normal for the more confident tutors to weave their own variations around such resources, whilst others follow the resources more closely. Given the novelty of the medium, a detailed script was supplied

which gave clear instructions to tutors (e.g. "switch to the whiteboard with the Nonaka matrix loaded"), and sample instructions for students (e.g. "now go to your breakout rooms to discuss Q3; record your notes in a single concept node ready to paste into the plenary concept map; in 15 minutes each group should return to the Plenary room").

3 Lyceum's user interface

From the student's or tutor's perspective, the important features of Lyceum are as shown in Figure 1 overleaf, showing the client's user interface. Lyceum currently has several applications, three of which were used in its first deployment. The *ConceptMapper* and *Whiteboard* were designed to support structured and freehand representations, respectively. In addition, a *ScreenGrabber* supports the ad hoc sharing of material from any digital source. We describe and illustrate the main features of Lyceum's user interface below.

Voice Conferencing. Headsets (headphones plus microphone) are provided as part of the course materials. On logging into the Lyceum server, students can see the names of any others present in the initial Common Room. Clicking the *Talk* button at the bottom-left of the window activates the microphone for speaking, which broadcasts to all others in the room (the quality is similar to AM radio, but good enough for foreign language students to be using the system to practise oral skills). Discussions take place in *Rooms* (e.g. *Plenary* and *Breakout* rooms) which can be given various access permissions (e.g. who can delete a Whiteboard). We have imposed minimal technical constraints on 'floor control': anyone can speak anytime. Some systems require the microphone to be 'passed' between participants, or for a chairperson to pass it. Lyceum participants manage by social agreement, learning how to take turns, and maximising flexibility for different kinds of meeting. Interactional fluidity is a key skill that newcomers learn, and an issue for future research.

ConceptMapper. The ConceptMapper enables users to share and organise ideas in a common space so that they can see what they have gathered collectively. They can create labelled, coloured nodes for spatial structuring into matrices (Figure 1), diagrams (Figure 2) or use as sticky notes (Figure 3).

Whiteboard. This workspace provides the digital equivalent to a whiteboard or flipchart, with tools for scribbling freeform shapes, plus tools for typing and drawing shapes (Figure 4). As with the other tools, whatever one person does is updated on all other screens in that room. Participants may wish to show small fragments of documents, web sites, CD-ROMS, emails, etc. to colleagues, such as a figure, table, or paragraph of text. Using the **ScreenGrabber**, these can be 'photographed' and added to a whiteboard as a resizeable object or background image.

4 Technical challenges and solutions

4.1 Technical challenges

To function practically as part of the university's infrastructure, Lyceum had to operate under some stringent design constraints:

- The system must work on **Windows PCs** over **dialup access** to the **standard internet**, via **unknown internet service providers.** (The recommended minimum PC to run Lyceum is a Pentium II, Windows 9x/NT, with 64M RAM, and a SoundBlaster32-compatible soundcard.)
- The system needs to support **multiple groups** (e.g. courses and research projects) on the same server. Maintaining different servers would cause a good deal of trouble and require distributing different versions of the client software.
- Because multiple courses can use the system, there may be **many simultaneous users**, thus creating a high load for the system, which must deliver acceptable synchronous responses to support conversation.
- Different groups of users **have different software requirements**; for example, other courses require different tools to those shown, such as a collaborative editor, modified look and feel to match a simulation scenario, or a graphing application for discussing data analysis.
- **Administering** the software (e.g. adding users to different databases) needs to be simple.
- As the system is complex to test, bugs may occur which users cannot always be relied upon to report accurately. Additional requirements therefore were that **bugs be automatically logged and reported,** and **software updates be automatically distributed**.

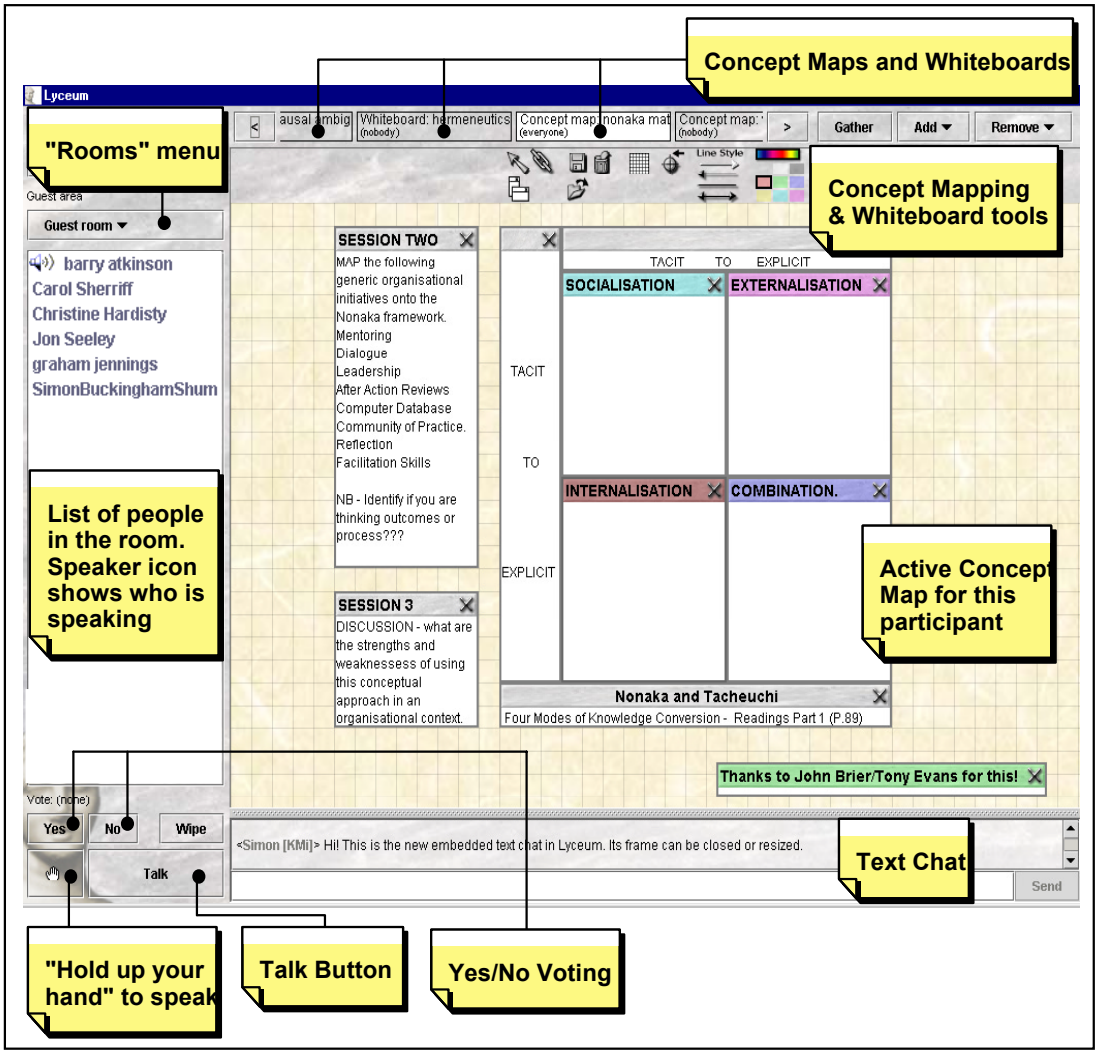

Figure 1: Layout of Lyceum's user interface (Java client)

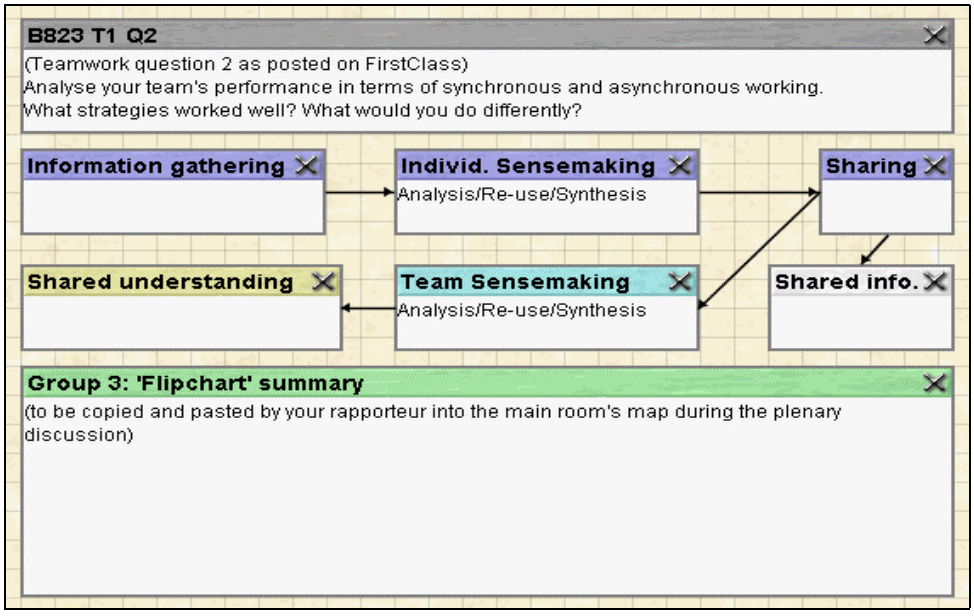

Figure 2: Using the ConceptMapper to represent a diagram

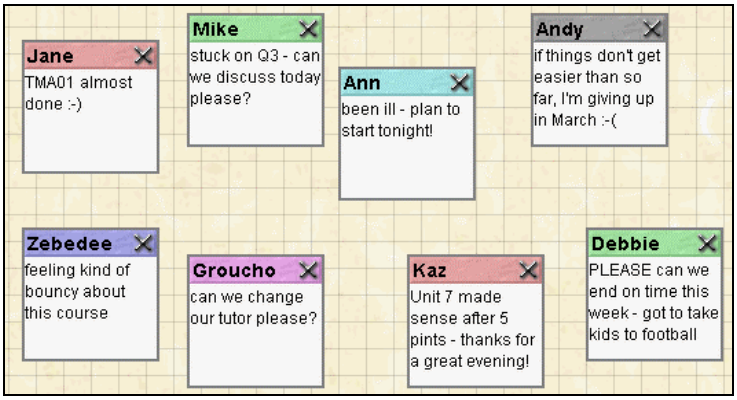

Figure 3: Using the ConceptMapper to post 'sticky notes', e.g. as students arrive in their Tutorial Plenary Room.

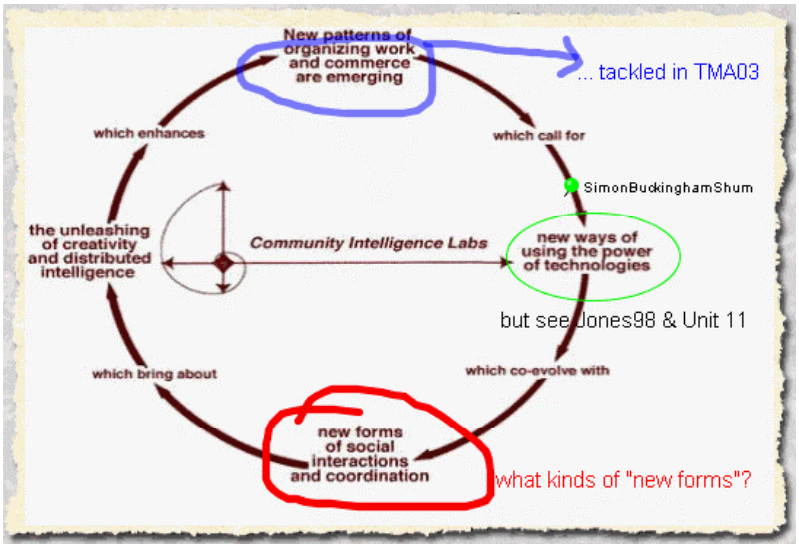

Figure 4: Using the Whiteboard to annotate a diagram (grabbed from a website).

4.2 Architecture for scalability

There are three core elements in Lyceum's architecture:

- **Client.** This runs on user machines (see the user interface above).
- **Master server.** The master server performs connection authentication, software updates (see below), and a variety of other services. It also provides 'directory' information including the list of rooms and groups available to the user, and information about the inhabitants of those rooms. It assigns particular rooms to each slave server based on approximations of the load at each slave. If one slave server goes down its rooms are automatically reassigned to other servers.
- **Slave servers.** The slave servers handle all events associated with a particular room. This includes users joining and leaving (tracked by the master server), data events in the room (e.g. users drawing objects on whiteboard, which must then be mirrored to other users), and so forth.

We estimate that the master server can cope with at least a thousand simultaneous users, using a feasible number of slave servers. Lyceum uses a proprietary voice conferencing codec, integrated seamlessly at the client side. We did not, therefore, have to deal with the technical problems of voice networking.

4.3 Course/group separation

The user database works on a hierarchical principle, such that on logging in a user is presented with the correct subset of Rooms for their work. Within a root group are subgroups, one for each course, which can be further divided as appropriate for a course (e.g. into regional groups with local tutors). Each group can contain multiple rooms and users. In this way, users on a course are not aware of (and cannot interfere with) users on other courses, unless they choose to meet up in a common room.

4.4 Advantages of Java

Lyceum servers and clients are implemented in *Java* [www.java.sun.com]. All parts of the program code are modularised, improving reliability as modules are updated without affecting others. This also improves flexibility for the user's client in important respects. Tools (such as the Whiteboard) are packaged in a Java 'jar' file, and use a standard software interface so that it can simply be plugged in. The code is modularised so that different combinations of client applications can be updated for different user groups when they connect to the server. Thus, a new tool may become available at a certain point in a course. The generic controls such as Room navigation, viewing participants in a room, and control buttons (Figure 1) are also modular components. These can be easily modified to provide customized interfaces for tasks like selecting rooms (e.g. replacing a menu with a pictorial map of rooms to click on).

Java provided several other advantages. Its large Application Programming Interface provided many useful features (e.g. JPEG image compression), and in our experience offered a faster, more pleasant development environment than C++. A disadvantage of Java is the client's increased memory requirement, reflected in the higher specification PC required for students on courses using Lyceum. Another factor for Lyceum was that Java was undergoing significant upgrades during our development, complicating design decisions. The 'moving target' nature of internet technologies is of course not peculiar to Java.

4.5 Maintenance support features

- **Automated software updating.** When the Lyceum client connects to the server, it reports the internal version numbers of each core component (jar file). If newer versions are available, the server automatically sends updates which the client self-installs.
- **Automated bug reporting.** Lyceum's automated bug reporting is a simple but important feature. If the Lyceum client encounters an unexpected error condition, it displays an error message to the user but also saves it as a disk file. The next time the user connects to the server, these errors are uploaded to the server which files and catalogues them, and can be inspected via the web administration system.
- **Web administration.** Almost all of the server can be administered via a Web-based interface, designed to be used by a non-developer after introductory training, to configure rooms, user groups and software versions.

5 Technical evaluation of first deployment

In its first large scale deployment on B823, Lyceum succeeded at a technical level in many respects, but failed in others. We had students from Europe, Australia, North America and Asia participating in meetings with voice latencies comparable to transatlantic telephone calls. Online tutorials were successfully held, and were particularly popular amongst students who lived long distances from where they would otherwise have been required to travel. However, by no means all students and tutors were able to get Lyceum running for a variety of reasons. Indeed, it is the number of factors that can impact voice conferencing that makes it such a challenge. Voice conferencing will always be more sensitive to network delays than text conferencing (synchronous or asynchronous). Specific complexities in getting voice over the internet working for hundreds of users included:

- Ensuring that students realise they need a higher specification computer than required by their previous work. No matter how much this was emphasised, there were still students who missed this.
- Students using work-based PCs for their studies can encounter problems with security 'firewalls' blocking voice data protocols.
- Some internet service providers block voice data completely, or at popular times due to network load; more general difficulties with obtaining good modem connections impact synchronous meetings more drastically than asynchronous conferencing.
- Sound cards in PCs vary in quality, impacting interaction and the quality of experience.
- There may be clashes with other software on the PC.

We learned some important development and organizational lessons with Lyceum. It was released to a very tight schedule due to underestimations of its technical complexity. Versions that had proven stable in extensive beta tests were substantially revised for release, leaving insufficient time for proper testing. The first release proved unstable and undermined some users' confidence in the whole idea of voice over the Net. Time pressure also led to insufficient communication with other key stakeholders, such as tutors and helpdesk staff. However, following these teething troubles in 1999, which mirror the typical processes of introducing any new technology into an organization, Lyceum is now fully in place as part of the OU's delivery infrastructure.

6 Lyceum's affordances for interaction and learning

CSCL technologies can support learning by *imposing* constraints on interaction, or by enabling educational interactions through *appropriate usage*. Voice groupware is a very recent development to have available for large scale distance learning, and we still are at an early stage in understanding its pedagogical niche. Lyceum imposes few interactional constraints specifically designed for learning contexts, but we can summarise its key affordances as a generic (discipline independent) medium that can support CSCL through appropriate usage:

- **Communication in distributed team working.** An important objective in many courses is for students to learn the social and technical skills required to work as part of a (fully or partially) distributed team. Lyceum supports synchronous team communication with voice, shared displays and text chat. There is nothing specific to "academic learning" in this respect—but it delivers scaleable voice groupware to 'the masses' by meeting the technical constraints specified earlier.
- **Shared visual displays.** Learning needs more notations than text, which has tended to dominate mainstream CSCL to date. We all recognise the power of progressively constructing or disclosing a diagram, or annotating an image, to enhance an ongoing commentary (by a tutor or student). Lyceum's shared workspaces are the virtual substitutes for the overhead projector, flipchart and whiteboard. The 'craft skill' of knowing when and how to use visual materials is similar to that in face-to-face, and remains the responsibility of the speaker (any digital document can be shared, via the ScreenGrab tool). A limit of all virtual shared displays is known to be the absence of expressive gesturing [16]. In Lyceum this can be accomplished using a *Gather* button which calls participants to a particular display, and once there, attention can be directed around the display by selecting Concept Nodes (changing their colour on all client displays), and by placing a personally named, coloured pin on Whiteboard objects.
- **Varied formality of representation.** The representational tools one provides can shape reasoning, by highlighting some kinds of information and hiding others. Thus, there are important cognitive differences between sketching with a pencil on paper (Whiteboard), versus using a structured diagramming tool (ConceptMapper) [7,15]. Lyceum's tools, as illustrated, provide both informal, (relatively unstructured) and more formal (structured) representations, which can be added or removed as desired by a tutor or course design team.
- **Developing meeting skills**. More specific to our management students is the value of being able to practise online skills in 'safe', structured and unstructured contexts, before they have to do so in business meetings.
- **Linking students with common interests/concerns.** The Web is ideal for hyperlinking individuals with common interests, however specialised. Lyceum simply adds the dimension of permanently accessible rooms for conversation, opening up new possibilities for CSCL. These include: one-to-one problem solving sessions, ad hoc 'masterclasses', special interest groups, or pre-tutorial/exam briefings. It also has interesting potential for enabling the more casual, social interactions that maintain intellectual and emotional support amongst distance learners. Students on different continents can now talk for free, or at local dial-up rates.

Summary and future work

Voice groupware is now becoming practical over the mainstream internet. This paper has described *Lyceum*, a system now in use at the Open University. We have described how Lyceum's design and development tackled some stringent design challenges. On the technical front, future work includes improving robustness and voice codec performance, the variety of client tools that can be offered to courses, and user interface refinements. We are also tracking web meeting products in order to build on their strengths whilst maintaining the advantage of being able to rapidly customize our own system.

On the pedagogical front, various projects are now studying Lyceum's learning and interactional affordances in depth (cf. [14]). We need a deeper understanding of what it means to be literate and socialized in voice conferencing, and the implications of a "24/7" synchronous medium for training staff and resourcing courses. We are hearing enthusiastic praise for Lyceum's potential from many tutors and students, but also understandable reluctance from others who feel deskilled in the new medium, who have had poor experiences using it, or who fear that face-to-face meetings may be abolished.

The key challenge is to design Lyceum's niche in synergy with face-to-face and asynchronous communication. To embed it successfully in new contexts, hybrid forms of CSCL need to be evolved, weaving pedagogical knowledge grounded in existing media around the new possibilities. Prototype hybrids will encapsulate a plan for different kinds of Lyceum meetings, around which are choreographed pre- and post-meeting activities. Future work must negotiate and map the pedagogical design space that voice groupware opens up.

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