Desktop multimedia environments to support collaborative distance learning*

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Abstract. Desktop multimedia conferencing, when two or more persons can communicate among themselves via personal computers with the opportunity to see and hear one another as well as communicate via text messages while working with commonly available stored resources, appears to have important applications to the support of collaborative learning. In this paper we explore this potential in three ways: (a) through an analysis of particular learner needs when learning and working collaboratively with others outside of face-to-face situations; (b) through an analysis of different forms of conferencing environments, including desktop multimedia environments, relative to their effectiveness in terms of meeting learner needs for distributed collaboration; and (c) through reporting the results of a formative evaluation of a prototype desktop multimedia conferencing system developed especially for the support of collaborative learning. Via these analyses, suggestions are offered relating to the functionalities of desktop multimedia conferencing systems for the support of collaborative learning, reflecting new developments in both the technologies available for such systems and in our awareness of learner needs when working collaboratively with one other outside of face-to-face situations.

Collaborative distance learning

What is collaborative distance learning? Why is it important? What are major questions that need to be addressed relative to its effective implementation? In this section, we introduce the analysis that follows by some definitions, some orienting comments, and some core research questions.

What is collaborative distance learning?

Collaborative learning can be defined in various ways, as can the characteristics that distinguish it from cooperative learning and group learning (Heeren,

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1996). Sometimes collaborative learning is used as a collective term, including both cooperative learning and group work. As an example of this, Hiltz (1995) defines collaborative learning as:

... a learning process that emphasises group or cooperative efforts among faculty and students. It stresses active participation and interaction on the part of both students and instructors. Knowledge is viewed as a social construct, and therefore the educational process is facilitated by social interaction in an environment that facilitates peer interaction, evaluation, and cooperation. (pp. 6–7)

Others make much more of the distinction between working as a group and collaborative learning. For example, Kaye (1992b) notes that “learners constituted into groups are not necessarily learning collaboratively” ... collaboration is “shared goals and an explicit intention to ‘add value’, to create something new or different through the collaboration, as opposed to simply exchanging information or passing on instructions” (p. 2). As a further contrast, some use the words “group” and “team” interchangeably when discussing those involved in a collaborative learning activity (see, for example, Briggs & Nunamaker, 1994) while others take considerable care when defining the different concepts (see, for example, Shaw, 1984). As a further distinction, the role of the instructor in collaborative learning is stressed by some and considered at most a background variable by others, in the latter case bringing collaborative learning and cooperative working into many points of overlap (Collis, 1994).

While such distinctions between the processes of collaborative and cooperative learning and between the entities team and group may seem more semantic than valuable, their nuances can make a considerable difference as soon as criteria for effective support are elaborated. However, because their application in practice often involves a blurring of distinctions, we will use the term “collaborative learning” in a broad sense in this analysis, as “the application of the individual efforts of two or more persons to a joint (learning-related) task” (Lim & Benbasat, 1991, p. 612). Furthermore, when the persons involved in collaborative learning are at least some of the time at a distance from each other in time or place or both as they work on their common tasks, we will call such a situation collaborative distance learning. This includes collaborative activities that take place synchronously – that is, when the participants are interacting with each other at the same time but from different locations – and those that involve asynchronous distributed collaboration such as when group members at various times access a shared workspace environment through a World Wide Web site. In the latter case, it is temporal rather than geographic distance which is relevant.

Why is collaborative distance learning important?

Collaborative learning has long been established as having value in education. Sometimes this value relates to the goals and nature of the learning task itself, as with a task that involves problem solving through the communal efforts of a group, each of which has a different speciality (for example with the "Jigsaw Method", Aronson, Blaney, Stephan, Sikes & Snapp, 1978). If, for example, learners are to progress in their capacity to work in teams for tasks such as multimedia software development, participating in a variety of experiences involving collaborative learning is generic to growth in the learning domain itself (Liu & Rutledge, 1996). But the value of collaborative learning is also seen more globally, with regard to the process of learning itself. Vygotskyian learning theory, for example, states that learning occurs as a socially collaborative process in which learners learn from interacting with each other (Davydov, 1995). Also, improving the individual's skills in working collaboratively is a desirable goal for social-strategic reasons (i.e., European students will benefit from frequent experiences in cross-cultural collaboration with students from other European countries in the context of the continuing evolution of the European Community; Trindale, 1992).

The widespread use of the World Wide Web has made feasible many new forms of collaborative learning activities, such as those that occur when learners in different parts of the world can work together on data collection and analysis projects, on the design and construction of new WWW-based resources, and in many other forms of learning activities that take advantage of the capacity to integrate communication with information access and organisation within a commonly accessible hyperlinked environment (Collis, 1996; Khan, 1997). The fact that WWW-based environments can be accessed independent of time and geographic distance has brought a new wave of possibilities for collaborative distance learning and a heightened frequency of participation in such possibilities to both school- and higher education.

Regardless of the manner of realisation of collaborative distance learning, there appear to be three dimensions always present (albeit often overlapping): a communication dimension, an information-handling dimension, and a coordination dimension (see for example, Dourish & Bellotti, 1992). Participants must communicate with each other, often in reference to stored or be-to-created resources, and in a way that integrates their individual and joint efforts.

What are major questions relating to the effective implementation of collaborative distance learning?

While collaborative learning has many points of advocacy, moving from this potential to effective realisation in practice has many difficulties. Some of these difficulties relate to the integration of collaborative learning activities into established instructional practice (see, for example, Schwab, Hart-Landsberg, Reder & Abel, 1992); some to the social and procedural problems involved with facilitating successful group interaction (Heeren & Collis, 1993; McManus & Aiken, 1995); some to the effective management and evaluation of the workflow aspects of collaboration on complex tasks (Collis, Andernach & Van Diepen, 1997); as well as a variety of permutations of these and other reasons. Regardless of the approach taken to their categorisation, all of the difficulties can be magnified when the collaborating participants are at a distance from one another, and thus not able to interact face-to-face and under the direct supervision of a teacher or moderator (Collis & De Diana, 1994). Such problems must be confronted with a mixture of effective learning strategies, group-management skills, and useful technological support. Although many research questions can be identified, a focus on guidelines for technological support of collaborative distance learning can be particularly useful, in that the rapid emergence of new forms of such support, in particular via the WWW and desktop multimedia conferencing and their convergence, is offering so many possibilities from which to choose. But technology should not be the driver for such decisions; instead there should first be an analysis of learner needs and then the potential appropriateness for a technology or a particular tool or application can be evaluated relative to those needs.

Thus in this paper we address the following three questions:

- What is core set of learner needs in collaborative distance learning?
- Which technologies are most appropriate for different combinations of this core set of needs?
- What is a methodology for evaluating a particular environment in terms of predicting its appropriateness relative to the core set of needs?

From responses to these questions, a broader question can be addressed:

- What are some major guidelines for the technological support of collaborative distance learning?

To address the first three questions, we present the results of three lines of analysis: (a) an identification of a set of 12 particular learner needs when learning and working collaboratively with others outside of face-to-face situations; (b) a general analysis of different forms of conferencing environments, including desktop multimedia environments, relative to their effectiveness in terms of meeting these learner needs; and (c) a formative evaluation of a prototype desktop multimedia conferencing system developed especially for the

support of collaborative learning. The final question is addressed following the summaries of these analyses.

Core problems in realising collaborative distance learning

Using the three generic dimensions of communication, information handling, and coordination, a synthesis has been made of a wide range of literature from not only the collaborative-learning research line, but also from CSCW (computer-supported cooperative work) and HCI (human-computer interaction) sources relating to group tasks and interactions. This literature base includes many exemplars, of which the following represent the diversity as well as including many further references within them: Ayre & Gottesman, 1994; Berlin, Jeffries, O'Day, Paepcke & Wharton, 1993; Collis, 1994; Collis, Andrenach & Van Diepen, 1997; Derycke, Smith, & Hemery, 1995; De Vries, 1994; Greenberg, Roseman, Webster & Bohnet, 1992; Grehan, Eglowstein, Thompson & Yager, 1991; Heeren, 1996; Kranz & Sessa, 1994; Nunamaker, Dennis, Valacich, Vogel & George, 1991; O'Conaill, Whittaker & Wilbur, 1993; and Slavin, 1995. From this synthesis, some major issues confronting learners in collaborative distance learning settings can be extracted and from these a set of core problems identified.

Communication issues

Communication is "the process by which information is conveyed from one entity to one or more other entities", where in the case of computer-supported collaborative groups, "these entities may be either humans or machines. When both parties are human, the information is interpreted by the recipient in terms of a context which may include individual biases, social norms, and the history of the interaction" (Lim & Benbasat, 1991, p. 612). Variations in these contexts can bring difficulties to communication. The patterns of communication among the participants can be diagrammed in forms such as a two-headed arrow, a circle, a chain, a wheel, and a "Y" (Fisher & Ellis, 1990), where the instructor may or may not be part of the pattern. Each pattern involves different needs in terms of leadership and consensus finding. Also, communication can be categorised in terms of concurrency related to time and location; communication is distorted whenever its contiguous nature is altered. Communication is affected by more than the words which are being said. Lim & Bensahat (1991) for example note the impact on communication of cues related to "social presence" when communication occurs in real-time: cues which may be paralinguistic (i.e., relating to the tone or voice, the variation in speed and use of pauses and levels of volume

to add nuance to speech); kinesic (i.e., relating to being able to see indicators such as gestures, body language, direction of gaze, and posture); and proxemic (relating to physical distance among participants and its social meaning, i.e., the social power related to where persons stand and sit relative to each other). When communication is derived of these cues, stresses in interaction may occur.

Needs relating to communication for distributed collaborative learning

From the many issues affecting communication among distributed collaborators, the following three seem to be particularly important:

– Com Need 1: *The need to provide timely and appropriate feedback to the group member who has expressed an idea or asked a question.* In face-to-face settings, group participants provide “concurrent feedback to the speaker that the communication is on track, by giving both auditory backchannels (‘mm,’ ‘uhu’) and visual evidence in the form of head nods and eye gaze . . . Where this feedback is absent or even delayed, the speaker’s ability to formulate efficient messages is reduced” (O’Conaill, Whittaker & Wilbur, 1993, pp. 397–398). Without such feedback, particularly when communication is distributed over time and/or distance, speakers may feel they need to repeat themselves even if not necessary or to miss the moments when they are not being understood. Also, speakers may continue on too long or fail to effectively link their comments to those which have been made before. These problems relate to social presence as an aspect of communication (and thus overlap with awareness indicators related to communication coordination). In asynchronous communication these problems are magnified.

– Com Need 2: *The need to take turns in speaking and changing the line of the communication:* Speaker switches should be smooth and not disruptive to the overall flow of the communication. In normal communication, speakers indicate in a number of informal ways that they are about ready to finish their conversational turns and also listeners can give cues such as leaning forward to indicate they wish to take over the communication. Close synchronisation of these sorts of cues is necessary and again relates to the social-presence aspect of communication. In distributed communication these multiple modalities are harder to provide, as is the close synchronisation necessary to let them serve as feedback to each other. In asynchronous communication the problems are again magnified.

– Com Need 3: *The need for both private messages and group communication:* Individuals should be able to speak to each other privately and in perhaps different ways than when they speak to and with their entire group. In distributed situations the ability to whisper an aside or catch the eye of one’s colleague needs a counterpart.

Information-handling issues

Collaborative learning involves the handling of information which is in some way shared by all involved. Such information must be commonly available to the collaborators, perhaps being also created by the collaborators as part of the process of their collaboration or as part of its product. One important variation in the information-handling aspects of collaborative learning is the extent to which information is explicitly generated by the participants or passively collected and distributed (Dourish & Bellotti, 1992), each with problems relating to selection, quality-control decisions, and storage. Information handling also involves issues related to the choice of the common editors and tools available to the collaborators for making use of shared information, as well as procedures to indicate who has the right to alter common information resources, how alterations can be noted, how new information is labelled and stored, and issues related to quality control of information (Hoffer & Valacich, 1993).

Needs related to information handling in collaborative distance learning

While many needs can be listed related to problems in information handling among participants in collaborative distance learning, the following seem pervasive:

– Info Need 1: *Needs related to the efficient storage, retrieval and sharing of information in ways that make sense to the collaborators individually*: While the WWW and its search engines have provided common tools for finding certain sorts of information, the locally relevant information of the distributed participants, in different forms such as local text files and course notes, is not likely to be tracked by any search tool. How does it become available for common use? Who makes decisions about what is stored and where it is stored, relative to file directories and hard disks as well as via non-electronic media? Also, procedures must be in place to track multiple versions of documents as collaborators work on them. The distributed collaborative setting brings with it special problems for making documents available, particularly multimedia resources, and for keeping track of multiple versions of documents (Hoffer & Valacich, 1993), although the common use of group-constructed WWW-based collections has become a general strategy for many groups.

– Info Need 2: *Needs related to defining and making available what might be called the group's collective memory*: In contrast to specific documents such as course manuals and working versions of documents, a group accumulates over time a "memory" of its own, a common set of minimally structured information of persistent value to the collaborating partners that needs to be close at hand to them as they work but which may not even have a written form (Berlin, Jeffries, O'Day, Paepcke & Wharton, 1993). Groups

come to remember what they agreed in earlier meetings, and where they left various notes to each other and also who tends to have what information. In collaborative distance learning, such group memory may have to be explicitly captured and labelled, tasks that require extra efforts not necessary if all collaborators can see and rifle through a pile of familiar resources on a common work table when they wish to refer to a certain document.

– Info Need 3: *Needs related to the process of flowing information through the group*: How does up-to-date and relevant information move to all collaborators? In the distributed situation, what is the equivalent of putting a message on the classroom blackboard, spreading a message among a group via casual contacts in the hallways, or handing out new sheets of information to those in the group?

– Info Need 4: *Needs related to a common work area to develop new information and documents*: Collaborators need some sort of common reference area on which to “spread out their work” and register their ideas as well as work on their documents. Providing a common workspace not only involves giving collaborators a common focus point for their work but also provides simultaneous access to notes and documents ranging from brainstorming-type scribbles to formatted charts and other forms of idea organisation (Nunamaker, Dennis, Valacich, Vogel & George, 1991). A common work area is more than a surface; it also involves the need to provide ways of supporting gestural (kinesic) and (para)lingual communication among the collaborators in relation to objects on the common workspace (Greenberg, Roseman, Webster & Bohnet, 1992). Providing such a shared workspace and the support necessary for collaborators to communicate as they use it to create new information and documents is a major problem in collaborative distance learning.

– Info Need 5: *Needs related to information overload and incomplete use of information*: Information may be presented faster than it can be processed. In addition, different media have different attention-grabbing properties and when multiple parallel activities propagate multiple parallel inputs of text, images and sounds, the learner can be swamped with a sensory overload of information. The collaborators need help in attention prioritisation and focus.

Group-process coordination issues

Group-process coordination requires strategies and tools that help the collaborators stay “in sync with one another” and keep their resources in order (Briggs & Nunamaker, 1994, p. 70). Coordination can pertain to the act of communication itself, such as tools to indicate that someone wishes to communicate with someone else or tools to manage the flow of communication. Coordination also relates to the needs of the collaborators to organise when and how long they will interact. Coordination can also involve procedures involved

with information handling, such as for data sharing among collaborators, for consistency among participants in terms of how they handle information, and for concurrency control among participants (procedures for taking turns in talking or controlling group resources or coming to decisions and consensus; see for example, Vessy & Sravanapudi, 1995, p. 90). Coordination also involves workflow management: keeping track of what is to be done, at what time, by whom, and to what standards (Van der Veen, 1997). Although project management methods are well known in business, they are not likely to be familiar to collaborative learners, especially when these learners are still students in educational institutions. In addition, coordination involves another aspect of support for collaborative learning: an aspect related to intragroup “awareness”. Awareness is defined as:

... understanding of the activities of others, which provides a context for your own activity. This context is used to ensure that individual contributions are relevant to the group’s activity as a whole, and to evaluate individual actions with respect to group goals and processes. This information, then, allows groups to manage the process of collaborative working ... whatever the task domain. (Dourish & Bellotti, 1992, p. 107)

Thus coordination is related to the management of the process of carrying out the learning task and also to the maintenance of good social harmony among the collaborators. Both strands of coordination offer problems to the participants in collaborative learning groups, particularly at a distance where positive group dynamics may be harder to generate.

Needs related to group-process coordination in collaborative distance learning

From the above, four needs seem particularly important:

– *Coor Need 1: Needs related to maintaining a positive atmosphere among the collaborators:* Without this, there may be conformance pressures, where participants feel reluctant to criticise the comments of others due to politeness or fear of social reprisals or of being negatively thought of in the group (Nunamaker, Dennis, Valacich, Vogel & George, 1991, p. 356). Conversely, there can also be pressures from lack of conformance in a group.

– *Coor Need 2: Needs related to meeting- and time-management support:* When participants meet to plan their collaboration or to discuss its development, they need to coordinate their schedules and agendas, and support for producing helpful notes and minutes for the current meeting. Handling this coordination at a distance and over time is more challenging than doing it face-to-face (Grehan, Eglowstein, Thompson & Yager, 1991; Kranz & Sessa, 1994).

– *Coor Need 3: Needs relating to group decision making*: At various times, the collaborators must come to consensus among themselves and for this procedures and sometimes tools, such as a voting mechanism, are needed (Nunamaker, Dennis, Valacich, Vogel & George, 1991). For the distributed collaborative group, the lack of the linguistic and kinesic cues about participants' individual reactions to a decision item normally available in a face-to-face situation must be accommodated (Weick & Meader, 1993).

– *Coor Need 4: Needs related to group awareness*: Information about the content of activities in progress must be continually available to participants. Issues related to who decides what information to provide and who can update a common overview must be handled (Dourish & Bellotti, 1992). In collaborative distance learning, “telepresence”, or a “collective sense of co-presence between/among group participants” (Buxton, 1992) is an important goal and metaphor related to awareness coordination.

Summarising needs in collaborative distance learning

In response to the our first research question, we suggest that these 12 need clusters while not exhaustive are likely to be common to a variety of collaborative distance learning situations and are likely to cause disruption to the success of those situations if not adequately addressed. We summarise them here in an abbreviated form:

Com 1: Provide feedback to the communicators

Com 2: Support turn taking while communicating

Com 3: Support both private and group communication

Info 1: Provide efficient storage, retrieval and sharing of information

Info 2: Define and make available the group's “memory”

Info 3: Support the flow of information within the group

Info 4: Provide a common work area to develop new ideas and documents

Info 5: Prevent information overload and incomplete use of information

Coor 1: Maintain a positive atmosphere among the participants

Coor 2: Provide meeting- and time-management support

Coor 3: Support group decision making

Coor 4: Stimulate group awareness

In general these needs are being addressed in collaborative learning settings with varying degrees of satisfaction and efficiency through a combination of planning and guidance by the instructor or moderator and through decision making among the collaborators themselves as to their working procedures (Heeren, 1996). Much research has gone on in education relating to strategies for managing such problems in collaborative learning, including the development of different methods for collaboration and even in instrumentation to coach learners in the use of those methods (see, for example, McManus &

Aiken, 1995). However, the responsibility of the participants themselves for self-regulation with respect to addressing these needs has become increasingly emphasised (Collis, 1994).

Regardless of the methods and instructional support for collaborative learning, when distances are involved some sorts of communication technologies are likely to be part of the learning setting. There is an increasing amount of research that supports the critical influence that the choice of communication technology and the design of any instrumentation used commonly by the learners can have on both the process and product of collaborative distance learning (see for example, Goodyear & Steeples, 1992; Jessup & Valacich, 1993; Heeren, 1996). In the following section, some of this research is highlighted. In addition, the 12 needs for collaborative distance learning will be mapped onto some of the various technologies to evaluate the adequacy of their fit.

Technologies for collaborative distance learning

Only an overview can be given here of the various technologies and types of instrumentation that can support collaborative distance learning; for fuller sources of information, many different books, conference proceedings, and collections of reports can be cited (as some of the examples, see Bauersfeld, Bennett & Lynch, 1992; Collis & Davies, 1995; Davies & Samways, 1993; Mason, 1994; Turner & Kraut, 1992). In this section, some major classifications for communication technologies are identified with particular attention given to the combination of audio, visual, and textual channels into a desktop-computer system. Following this, five of the types of technologies are mapped against the 12 learner needs identified above.

Audio, audio-video, and data communication

The most simple categorisation of communication is one defined by modality: audio, (audio+) video, and data communication. Audio communication occurs mostly via telephone; video communication through various transmission options such as public or private video-conferencing networks, public telephone networks via ISDN-2, or dedicated leased lines, and in limited form via data-communication networks such as the Internet; and data communication via networked computers. Conferencing (or teleconferencing) is the general term used for interactive communication via these modalities. Some desktop-conferencing systems and in particular WWW environments allow the hyperlinked integration of information, communication, and tools for collaboration. Environments vary in the stress they give to the support

of real-time or asynchronous communication, and in the balance they offer between communication and information-handling needs. Variations focusing on simultaneous interaction among distributed participants include document conferencing (participants view the same whiteboard or computer-screen window in real-time and in different ways can manipulate the shared window); application sharing, (participants not only manipulate a common window but simultaneously can share a common software package); audiographics (involving the combination of audio and document conferencing through separate communication channels); data conferencing, (in which voice and document conferencing occur through the same communications channel); and desktop multimedia conferencing (combining audio, video, and some combinations of document, data, and application conferencing via a single desktop computer environment). Other variations focus more on asynchronous communication and information handling, such as WWW sites, but can offer within them tools to support simultaneous interaction among participants. In general, the trend in all such environments is toward integration of functionalities and of modalities of communication, with a major distinction being the stress given to hyperlinking and the use of WWW protocols contrasted with the stress given to the support of quality in audio- and video real-time communication. As two general types of support environments for collaborative distance learning, desktop multimedia conferencing systems and multimedia WWW sites can be useful to focus upon in some further detail.

Desktop multimedia conferencing systems

Desktop multimedia conferencing systems are only now evolving, technically and in the marketplace. Standard terminology for such systems, and standard functionalities, have not yet stabilised. However, a general set of characteristics is emerging: various hardware/software/networking components are combined so that through their interconnected desktop computers, collaborators are able to simultaneously:

- Talk with and see each other while communicating, as well as communicate via text
- Not only see one's collaborator but also his or her surroundings
- Exchange and view full-motion video, voice, images, and data, while in audio and/or video contact for communication and coordination
- Share and conjointly edit files, reports, charts, diagrams, through application sharing and shared work areas, while being in audio and/or video contact for communication and coordination

Various analyses of currently available desktop conferencing systems have been made, comparing the functionalities offered by such systems as well

as the hardware, software, and network requirements of the systems (see, for example, Desmond, 1995; Mize, 1996). The currently available desktop multimedia conferencing systems seem to reflect two differing backgrounds with respect to technology and applications: videoconferencing backgrounds, focusing on tools for real-time video presentations; and computer-based backgrounds, focusing on interactive shared access to computer-based (multimedia) resources. Different functionalities are emphasised in products from these different backgrounds.

Videoconferencing emphases

Important considerations in desktop multimedia systems that reflect a videoconferencing-oriented background include features such as focusing functions, for both auto-focus and manual focus; self-view portraits; handset and handfree options for audio; adjustment of microphone and camera pick-up angles; adjustment for audio including mute functions; provision of both portrait and document cameras; reduction of parallax error so that eye-contact between participants is as natural as possible; high-quality video and audio quality, involving, for images, aspects such as global quality, colour, brightness, background stability, speed in image reassembling, outline definitions and reduction of the 'dirty window' effect; and function keys and status icons for video and audio signalling, such as icons to allow the user to toggle a call between voice-only to voice and picture or to freeze and unfreeze an image (Clarke, 1995; O'Conaill, Whittaker & Wilbur, 1993).

Computer-based emphases

Important considerations in desktop multimedia systems that reflect a computer-oriented background include functions that support information-sharing tasks, such as file transport, internetwork connections, workgroup scheduling, access to shared databases, collaborative document editors, access control, data search and retrieval tools, archiving functions, task routing and tracking, forms and report creation, tools for managing structured information, and tools for managing transaction-based data. Computer-based emphases also include tools for managing organisational communications, such as messaging, structured and on-going group conversations, managing schedules, discussions about a shared document, and face-to-face communication (Ayre & Gottesman, 1994; Stevenson, 1993). There may also be functions to support brainstorming and idea generation, such as tools for group outlining; functions to support idea organisation; and functions that support the organisational memory of the group, such as a group glossary, tools for ready access to past agendas and documents; and tools which generate meeting reports (Kranz & Sessa, 1994; Nunamaker, Dennis, Valacich, Vogel & George, 1991; Salemi, 1994).

While such generalisations are increasingly blurred in practice, they point out the constraints in making overall comments about the current range of “desktop multimedia conferencing systems”. At least such systems all have in common being accessible to the collaborator through a personal computer; offering real-time communication in at least two modalities and perhaps also supporting asynchronous communication; offering various coordination tools; and offering some form of information handling, both in real time and using stored (multimedia) resources. Desktop multimedia systems are typically proprietary, requiring users to have similar commercial systems, extra equipment such as desktop cameras and microphones, and connection via ISDN or other sorts of digital networks.

Multimedia World-Wide Web sites

In contrast, a major characteristic of multimedia WWW sites that include tools to support collaborative distance learning is that such sites are evolving out of tools and functionalities available generally to all those with access to the WWW via the Internet. Therefore the proprietary, and integrated, systems typical of desktop conferencing are replaced by a pastiche of combinations of tools to support collaborative distance learning. Such combinations can include tools for real-time text, audio, and video conferencing, although the latter two only occur at a fairly primitive level compared to their desktop multimedia system counterparts. But, the primitiveness of the audio and video functions are balanced by the sophistication of the functions for information handling and for resource access, far beyond what is typically available via proprietary desktop systems. Tools such as the BSCW (“Basic Support for Collaborative Work”, German National Research Centre, 1996) allow collaborative work on communal resources of various modalities independent of both time and distance, via the WWW, although there is no convenient way to couple access to the shared workspace with real-time communication among distributed collaborators.

Relating various technologies to learner needs in collaborative distance learning

How can learner needs be related to different technologies for collaborative distance learning? Table 1 maps the 12 needs for collaborative distance learning developed in response to our first research question against a set of four different technologies – audio conferencing, video conferencing, desktop multimedia conferencing, and multimedia WWW sites – in order to identify which technologies offer in theory the most effective support for which learner needs.

It appears, in theory at least, that desktop multimedia conferencing has the best potential to meet the set of 12 identified needs, in an integrated manner, when these needs emphasise real-time interaction among distributed participants. De Vries came to a similar conclusion with regard to communication needs in distance education more generally (1994). In contrast, when cost and convenient access are critical variables, and when access to distributed, hyperlinked resources is more important to the collaborators than seeing and hearing each other during a common period of interaction, then multimedia WWW sites are to be preferred.

But, while desktop multimedia conferencing seems the best current solution as an environment type, for the 12 needs that were identified for collaborative distance learning when real-time communication is critical to the collaboration, it is not enough to stop at such a global conclusion. There are other criteria that must be applied to a decision for a particular configuration of multimedia desktop conferencing, criteria that relate to the eventual usability of the system and its user interface. That it is not easy to apply these criteria in practice will be demonstrated in the next section in which a particular multimedia desktop conferencing environment, designed especially in support of collaborative distance learning, is evaluated.

Evaluation of a prototype desktop multimedia conferencing environment for collaborative distance learning

In the previous sections we identified desktop multimedia conferencing as the best overall solution for support of collaborative distance learning, when natural communication and group-presence aspects are particularly important. But we also concluded our analysis by introducing other considerations related to the usability and user interface of the instrumentation used in a desktop multimedia conferencing environment that affect the theoretical potential of a technology type. In this section, we consider in more detail some of the specific aspects of a multimedia desktop conferencing system, by reporting the evaluation results of a technical audit of one particular desktop multimedia conferencing environment designed for distributed collaborative learning. Through this specific audit, further insights can emerge relative to the overall question of this paper: What are guidelines for the technical support of collaborative distance learning? The environment is the "Co-Learn" system (Kaye, 1994, 1995). We first briefly describe the system and its motivation, and consider the system, as conceptualised, relative to the 12 needs of collaborative distance learning developed earlier in this paper. We then will describe the method used for an evaluation (or usability audit) of the system. After this, we give some key results of the usability audit (abridged

from Smith, 1994). We conclude the section by summarising some of the recommendations made for revision of the Co-Learn system and re-express these to other desktop multimedia conferencing systems.

The Co-Learn system

Co-Learn was the name of a project, a consortium, and an ISDN-based desktop multimedia environment for collaborative distance learning. The project was one of approximately 20 projects funded by the Commission of the European Community in its third phase of the "DELTA Programme" (Bates, 1995). Co-Learn as a project had the general goal of "helping to develop the concept of 'third-generation distance learning', in which communication between and amongst learners, tutors and resource persons in a 'virtual resources centre' is seen as being a key element of a learning programme" (Kaye, 1992a). Collaboration among participants at a distance from one another was to be particularly supported, as were other modes of teaching and learning. To do this, the project consortium, over a three-year period (1992–1994), attacked the task of designing an integrated groupware environment for collaborative distance learning, based on personal computers connected via ISDN links. A strength of this integration was the availability of both synchronous and asynchronous communication within the same environment, as well as the support of not only collaborative but also lecture-type learning and tutor-learner interaction. The system was developed before WWW functionalities were feasible candidates for its components.

The project had as its main task the design and implementation of the Co-Learn desktop multimedia environment, fine-tuned to various educational and training scenarios, represented by 13 pilot testing sites in France, Spain, Portugal and Scotland. The consortium invested much effort in analysing the potential user requirements for the system and in considering its user interface, particularly at the metaphor level (Derycke & Kaye, 1993; Kaye, 1994). Based on this analysis, Figure 1 shows the metaphor used for the Co-Learn environment,

To realise this metaphor, it was decided that the environment itself was to provide:

- Support for real-time teleteaching, or remote lecturing from one to several sites, in conjunction with courseware (slides, diagrams, etc.) that have been downloaded to, or installed on, the learner workstations before the lecture, thus providing a remote 'electronic blackboard' facility, via local video projectors. The trainer was to be able to control the presentation on the remote blackboard and point at different parts of the screen. After the formal lecture phase, learners were to be able to ask questions via an

Table 1. Mapping of 12 learner needs for collaborative distance learning and various technology environments as support for those needs.

Learner needs	Technological environment			
	Audio conferencing	Video conferencing	Desktop multimedia conferencing	Multimedia WWW environments
Com 1: The need to provide feedback to the speaker	Some, depends on procedures used by group	Potentially good	Moderately good but depends on system	Weak, generally occurs via asynchronous mail
Com 2: The need to take turns while communicating	Some, depends on procedures used by group	Some, depends on procedures used by group	Some, depends on procedures used by group	Weak, generally occurs asynchronously
Com 3: The need for both private and public conversations	Poor	Poor	Possible, depends on tools available	Good; email and asynchronous newsgroups and discussion systems
Info 1: Needs related to the storage, retrieval, and sharing of information	Poor, must be done individually by participants	Poor	Possible to good, depends on tools available	Good
Info 2: Needs related to the group's memory	Poor, must be done individually by participants	Poor, must be done individually by participants	Possible to good, depends on tools available	Possible to good, depends on tools available
Info 3: Needs related to information flow through the group	Poor to possible, depends on type of information	Poor to possible, depends on type of information	Possible to good, depends on tools available	Good

Table 1. Continued.

Learner needs	Technological environment			Multimedia WWW environments
	Audio conferencing	Video conferencing	Desktop multimedia conferencing	
Info 4: Needs related to a common work area	Poor	Poor	Possible to good, depends on tools available	Possible to good, depends on tools available
Info 5: Needs related to information overload	Poor	Poor	Possible to good, depends on tools available	Poor to good, depends on tools available
Coor 1: Needs related to a positive atmosphere	Possible	Good	Good	Poor to possible
Coor 2: Needs related to meeting and time-management support	Poor	Poor	Possible; depends on tools available	Possible; depends on tools available
Coor 3: Needs related to decision support	Poor	Poor	Poor to possible; depends on tools available	Poor to possible; depends on tools available
Coor 4: Needs related to group awareness	Possible, affected by skills of leader	Good	Possible to good; depends on tools available	Poor to possible; depends on tools available

Figure 1. Metaphor used for the desktop environment.

audio channel, with turn-taking being controlled at the server site. This activity takes place in a “virtual lecture hall”.

- Real-time teleassistance, allowing connectivity between the server site and up to four client sites, where the tutor’s screen can show the status of each of the learner’s screens, the tutor can work with one or all of the students at the same time and both real-time and asynchronous messages can be exchanged. This interaction takes place in a “study room”.
- Real-time multimedia conferencing, for a small group of participants (up to five) using the setting of a “virtual room for collaborative work” and the metaphor of a workshop. Each participant would have a private space for documents and a way to move them into the public discussion space for synchronous group discussion. Depending on network capacity, videoconferencing was also to be possible.
- Asynchronous computer conferencing, with tools for free discussion, voting and private exchanges, as well as possibilities for voice annotation. The setting for this set of functions was that of a CMC room, using the metaphor of a forum.
- A database of multimedia courseware objects (text and graphics with sound annotations) that teachers and trainers could develop themselves with Co-Learn tools provided for the purpose, through the metaphor of the “courseware library” (see Kaye, 1992b, 1995).

The planning for the Co-Learn system was ambitious. In theory and planning, it seemed to offer direct support to most of the 12 needs for distributed collaborative work cited earlier in this chapter. The communication needs were served by the audio conferencing and the tools available in the Workshop and Forum components. The information-handling needs were addressed in the Lecture, Workshop, and Forum components. Coordination Needs 2 and 3 were supported by tools in the Workshop and Forum while Coordination Need 4 had potential support in each component, via the “Welcomer Tool”, showing who was present in real-time settings.

With such high potential, how did the system evolve in practice? Was its design conducive to the effective support for collaborative distance learning? To respond to these questions, we next describe the procedure and outcomes of an “usability audit” of aspects of the Co-Learn system which was carried out when the system was still in prototype form (Smith, 1994). There were also Co-Learn field trials which partly overlapped the technical audit as well as continuing after the audit (see Smith, 1995; Croisy, Clément & Barne, 1995; G.A.T.E., 1995). For space reasons, we cannot report the field-trial results here; However we can note that the field-trial results provided substantial corroboration of the usability audit’s findings.

Usability audit of Co-Learn: Method

In this section, we briefly review the functions of an usability audit in general, and the procedure that was employed for the usability audit of Co-Learn.

Functions of a usability audit

A usability audit or evaluation attempts to gauge how usable a system will be for its intended users in the intended context of use. Usability is an attribute a system is said to have if it is easy to learn and use to achieve the user’s goals (Nielsen, 1993). Usability testing aims to identify ways in which a newly developed system or system concept could fail to be usable to its intended audience. Usability testing involves exercising a system (concept, mock-up, prototype, final system) in as near as possible the intended usage situation. When the system is being exercised, the evaluator observes and records significant incidents which prevent the user’s tasks from being performed easily. A usability failure may for example, indicate that the user has difficulty understanding the system, that the system behaves inappropriately in a particular situation, or that the system is failing to convey the right message to the user about what he has to do. Interpreting what part of the system’s design causes these failures is not straightforward. A major function of an usability audit is to report problems; thus a summary of the results of such

an audit will not be a balanced overview of strengths and weaknesses of a system, but rather a targeted focus on areas where improvement is desirable.

The usability audit of Co-Learn: Specifics of the procedure

The usability audits of Co-Learn Version 0.0 and Version 0.1 were primarily performed at the ICBL (Institute for Computer Based Learning) at Heriot-Watt University in Edinburgh but also through trials carried out in two other sites. The audit was limited to those parts of the Co-Learn system that were available and functional in Version 0.0 and Version 0.1 between November 1993 and August 1994. Version 0.0 was not yet an integrated system. It was comprised of four separate components: the Workshop for real-time multimedia teleconferencing, the Lecture for real-time teleteaching (point to point), the Study for real-time teleassistance (point to point), and the hypermedia editor as an aspect of the Library. Evaluation focused on the Lecture and the Workshop. Version 0.1 provided a launcher which integrated some of Co-Learn's client-server administration operations with the existing Workshop and Study and with a new Forum and Lecture (multi-point). Co-Learn was exercised and observed in 42 test situations. In every test or usage situation, incidents or user comments that highlighted usability problems were recorded. Methods of observing and recording included direct observations, audio and video recordings, note taking, and screen recording. All recorded incidents were entered into a specially-built "usability defect database" after being classified. The database contained defect records with fields related to the status of the defect (fixed or not, etc.); description of the defects; location of the defect; a rating indicating severity of impact of the defect; the user interface element in which the defect was revealed; and the implications of the defect. All problems were communicated directly to the developers throughout the nine months of usability evaluation via electronic mail. Fixes were further tested and the status of the defect changed in the database in accordance with the test results.

Defects were also classified relative to their relationship to the system's conceptualisation (including its metaphors), to its behaviour, or to its representation. Over 250 defects were entered into the database in the nine-month evaluation period. About 25% were fixed by the developers. These were primarily serious or critical functional defects or minor usability defects. However, a number of serious and critical usability defects could not be fixed easily because many were deeply rooted in the system's underlying structure which was determined (sometimes implicitly) by the developers' conceptions (or rather misconceptions) of teaching/learning activities.

In the following section, we summarise only some of these defects, choosing those with the most generalisable message for other desktop multimedia

conferencing systems for the support of collaborative distance learning. Full information is available in Smith, 1994.

Key results of the usability audit of Co-Learn

The following observations and recommendations from the Co-Learn usability audit seem most generalisable to current multimedia desktop conferencing environments:

1. Using a virtual learning organisation as the metaphor for an environment in which learning activities take place supports a critical requirement for a collaborative distance learning environment: through it people involved in the activities have a sense of cohesion through a shared context. The subdivision of the activities along a spatial (rooms) rather than temporal (time-related activities) dimension was however judged to distort the subsequent use of the system.
2. The on-screen visualisations involved gimmicks such as the need to “turn” the door knob on a sketch of a door via mouse manoeuvres in order to enter the “Administration Centre” of the Co-Learn system. These kinds of effects were included to make the environment look as realistic as possible, but quickly became annoying after an initial usage of the system.
3. The visualisations and metaphors used in some of the areas, particularly those relating to the access privileges available only to Co-Learn course administrators, were misleading to other users, who had to learn through being denied access that such tools were not for them to use.
4. With respect to the procedures for the Administrator to enter data for various courses, the rostering of the Co-Learn “rooms”, and user data, the audit found many serious inconsistencies, awkward and redundant “over-atomised” and time-consuming steps. Data was difficult to alter, and the Administrator had no tools for regrouping of learners, for example, once a course had started.
5. According to the usability audit, a major problem in Co-Learn was inconsistency in what the user was allowed to do in different rooms and situations. Users did not seem to know that they could switch roles, for example, as learners, or tutors, or resource developers, yet different functions were available to these different roles.
6. Telepresence support was limited by poor representation of who else was in a room and what they were doing. Names of those who have the right to enter a certain room in a particular course were shown in the left column of a particular tool, and names of those actually present in the room at a given time were shown in the right column. However, this “welcomer tool” was not available in all rooms in the same ways.

7. When audio was being used there were no indicators of who was talking. The listener had to recognise the voice or the speaker must remember to always introduce himself or herself before speaking. The absence of video as part of Co-Learn was thought to be a disadvantage by some users who found it difficult to understand what was happening at remote sites during a real-time session.
8. The usability audit indicated that considerable confusion existed for users of Co-Learn by the relative representation of the concepts “course”, “teaching session” and “room”. Courses were a main organising entity in Co-Learn, but were not used consistently. Courses were defined in terms of how they made use of various combinations of rooms, each with distinct tools available. Such a course substructure does not reflect the more natural subdivision of a course into components which use multiple pedagogies to study a single topic. Why couldn’t a group discussion take place in the Workshop as well as the Forum, for example? But the computer conferencing tool was only available in the Forum.
9. A very familiar organisational concept to students, the time of the next class or group-meeting session, was never made available to them; all they got was overall information about a “course” and the rooms used in a course. A metaphor of an agenda would have been more appropriate than the floor plan of a set of rooms, in relation to the limited amount of organisational information that was made available to learners.
10. Problems resulted from the fact that importing resources into the various rooms was difficult and involved inconsistent processes between the different rooms. Furthermore there was no facility that allows a tutor to create a resource during a live session in the Lecture room, as is so often useful when one wishes to “write something on the blackboard” in response to a question during a lecture.
11. A major problem was the different ways in which audio communication was handled in the Lecture, Study and Workshop areas, where there were not only inconsistencies, but a lack of awareness of the importance of hands-free speech and the lack of sound amplification (the assumption was that of an individual user, using earphones) as well as the difficulties in passing microphones around in order to speak. Troublesome problems with respect to echoes and time lags and with respect to microphone pickups being too little or too much were also present in Co-Learn.
12. The user was often not aware of which aspect of the distributed environment he was dealing with – the server or a client. When things were going wrong, where was the problem? Rather than trying to make the client-server aspects of the design of a distributed environment transparent to the user, as was the intention with Co-Learn, perhaps learner

frustration can be diminished if he or she is better aware of where it is that failures are taking place (it is not always something that the learner did wrong!). The lack of consistency between the environments the user needs to access a remote server and the environments available to him locally once connected to the server, will remain a problem for distributed learners for a long time.

Implications of the findings for a revision of Co-Learn

The usability audit of Co-Learn concluded with a number of recommendations for the Co-Learn consortium but also for other collaborative distance learning projects. The audit found inconsistent metaphors, non-integrated pedagogies and inconsistent conceptualisations to be central problems in the design of the instrumentation for Co-Learn. It urged use of a simulation of the intended system as early as possible with representative users (Smith made just such a simulation for some of the usability audits) in order to capture such inconsistencies quickly.

The audit emphasised the care which is necessary for the selection of metaphors for a desktop multimedia system for collaborative distance learning. In a later paper, Derycke, Smith & Hemery (1995) argued that the rooms metaphor drove the Co-Learn development in the wrong direction, an activity-space orientation incompatible with the desktop environment rather than an activity-time orientation more closely fitting the need to synchronise real-time interactions as well as time-sensitive asynchronous interactions.

With regard to the representation aspects of Co-Learn's user interface, the recommendations relating to the need for consistency among different areas of the system are of direct relevance to other desktop systems. Perhaps of most importance are the recommendations relating to the impact of poor telepresence in such systems, limiting awareness both of others and of one's self. Improving such telepresence will continue to be a major need for systems supporting distributed interaction. Ball, in an evaluation of another desktop multimedia environment for distributed collaborative learning, the ECOLE System (1995), found many of the same problems that were found in the Co-Learn audit and in particular, also found awareness problems in the design of the system, particularly with respect to cursor control in screen-sharing applications. Ball also found the real-time audio aspects of the collaborative system attractive in theory but problematic to realise in practice. When audio is dysfunctional, it can distort telepresence rather than help it (Bradford, 1995).

The usability audit as a methodology for evaluation of systems for the support of collaborative distance learning

The usability audit was a productive methodology for the evaluation of the Co-Learn system, and appears useful to recommend for other products at the formative evaluation stage. The use of a simulated version of the future system allowed a large number of respondents to walk through the intended functionalities of the system and identify potential inconsistencies and unclear design decisions. Indexing and prioritising problems via a data base is a systematic way to streamline communication with developers with respect to system adjustments, useful particularly when rapid prototyping is the development method being used. (For another example of the application of the usability audit during prototyping of a complex support system, see Verwijns, 1997).

Guidelines for the technological support of collaborative distance learning

The results from the three strands of inquiry reported above – user needs analysis, general consideration of technology type relative to user needs, and usability audit of a specific system – can be synthesised in order to address the broader question: What are some guidelines for the technological support of collaborative distance learning?

From the user-needs perspective, the 12 needs we identified early in this paper seem to capture many of the core aspects of supporting collaborative distance learning. These user needs should continue to be examined in other studies, so that a core set of reference criteria for subsequent systems aiming to support distributed collaborative learning can emerge. The particular implications of integrating tools for collaboration within hyperlinked WWW-based courses may lead to further revisions of the set of needs.

From the technology-choice perspective, some major points of consideration seem to relate to (a) the relative importance of communication and information-handling needs, (b) the nature of the distance involved in the learning setting, and (c) the nature of the technological support that can be made available to the distributed participants.

From Table 1, a major distinction in user needs affecting technology choice can be seen. This distinction relates to the relative importance of participant communication compared to information handling. Partly this relative importance will depend on the educational context of the collaborative learning, the nature of the task, and the amount of structure and guidance being provided by an instructor. Learning situations where the product of collaboration is emphasised over its process may be better served by systems with relatively

strong information-handling functionalities and whose group-process coordination tools emphasis project and time management. However, learning situations where the process of collaboration, and the nurturing of all those within the process to deeper understanding of complex issues, may be better served by technologies where communication and the social aspects of group coordination are emphasised.

These reflections lead to the following general guideline for the choice of technological support of collaborative distance learning:

- Analyse the relative importance of product vs. process for the collaborative learning activity. When product is emphasised, technologies with good support for the set of five information-handling needs and for the coordination needs relating to time- and project-management may be best, such as multimedia WWW environments and desktop multimedia systems reflecting a computer rather than video-conferencing background. When process is emphasised over product, then technologies emphasising real-time communication and the social aspects of group coordination, such as video-conferencing and desktop multimedia systems reflecting a video-conferencing background, may be the best choices.

Complicating the above conclusion is the nature of the “distance” involved in the collaborative distance learning situation. It may be that the group members never have the opportunity to work together face-to-face or to build a sense of social identity except through their interactions via a technological system. In this case, the group-process coordination needs relating to group awareness and a positive atmosphere in the group may have priority in order for the group to function and systems which support comfortable and natural communication among the members, both in real-time as a group but also through private messaging via e-mail, may be most important. However, it may be the case that group members do have occasion to interact with each other face-to-face, but will be using the system to support their collaborative activities as a common workspace, which can be accessed individually and atemporally as well as when group members are actually working together at the same time. In this case, the efficiency of the information-handling support of the system, particularly relating to Info Needs 1, 3, and 5, may be of major importance. Thus a second general reflection about the choice of a technology to support collaborative distance learning is: How physical is the distance involved? Must the system support all interactions among the group members or only some? A guideline from this is:

- The choice of a technological support for groups whose members can rarely or never interact with each other face-to-face should give priority to communication and the social aspects of group process. The choice

of technological support for groups whose members have the chance to interact with each other on occasion in face-to-face settings can focus more on the information-handling needs of the group, and the support of individual asynchronous access of the support environment.

A different perspective on technology choice relates to the rapidly emerging convergence of functionalities for both real-time and asynchronous communications, and for the integration of tools supporting all three categories of learner needs (communication, information handling, and coordination) into single systems. The Co-Learn system in 1995 was advanced in that it explicitly integrated these functionalities and tools, but such combinations are increasingly becoming routine. In addition, desktop multimedia systems of a proprietary nature are gradually being joined by collections of integrated tools available through WWW environments in terms of the functionalities available to distributed users. The desktop multimedia systems, usually linked by ISDN, have the advantage of better-quality audio and video communication than WWW-based environments, but are limited in a practical sense by their proprietary natures to a relatively small number of users with access to the particular software and hardware systems (generally not compatible with other systems). In contrast, WWW-based multimedia environments, with an increasing range of tools for both real-time and asynchronous communication, as well as tools for project management and information-handling needs, have the advantage of broader access possibilities, and the possibility of evolving over time the combination of tools that best fit the needs of particular learning situations. The disadvantage of this evolutionary approach is that the patchwork-like combinations of tools and functionalities which can be linked together in a WWW site may not only bring technical problems to user support but more importantly a lack of metaphorical integration of the components for the learner. The usability audit of Co-Learn showed clearly that the metaphor linking the various functionalities in a system for the support of collaborative distance learning has an important effect on learner reaction to the system, and productive use of the system. These reflections lead to a third general consideration and an associated guideline.

When a situation exists in which distributed learners can make use of common desktop multimedia systems (a situation in which the institution through which the learners are associated has in advance committed itself to the set-up and support of a particular proprietary system and its maintenance at various remote locations), then the aspects of such systems relating to their quality real-time communication support can be emphasised. When however, the learners in collaborative groups will be accessing their common support environment from a variety of non-associated locations, then multimedia

WWW-based systems or tool combinations offer a powerful advantage in terms of accessibility and affordability. Thus a last guideline:

- When locations for collaboration are well defined and well supported by a common institution, then desktop multimedia systems offer many advantages. When locations for collaboration are not well defined and not well supported by a common institution, then WWW-based systems for collaboration may be the technology of choice for collaborations where information-handling needs are of any consideration.

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