CYCLADES: A Distributed System for Virtual Community Support Based on Open Archives

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Abstract

This paper is about support for the exchange of information and knowledge among researchers. We introduce the concepts of open archives and grey literature, which provide valuable sources for researchers who work alone. We analyse how users exchange information and knowledge and introduce communities to more adequately reflect the nature of human information and knowledge exchange. Finally, we present the functionality and implementation of the CYCLADES environment—a distributed and open collaborative virtual archive environment based on open archives, providing several services supporting individual researchers as well as communities of researchers.

1 Introduction

The free flow of scientific information and knowledge across disciplines and cultural and political borders is not the case today. Clearly during the last centuries and decades progress has been as far as the process of production and distribution of scientific publications is concerned. Today, commercial publishers and online bookstores facilitate the global distribution of existing literature such as books and journals. However, in general, the process of publishing a book or journal article takes a long time—often several months, sometimes even years. Furthermore, being commercial enterprises publishers think and act economically and sales arguments have considerable influence on the selection of authors and topics that are published and often the prices for the published literature are high. The situation for scientific conferences is similar: the process of reviewing and publishing takes a long time and the participation at a conference and/or the purchase of conference proceedings are often expensive.

The advent of the Web and other Internet services has improved the situation, but the amount of information available on the Web is so huge and unfiltered that it is sometimes rather difficult to find high-quality scientific literature. Open digital libraries are promising in this respect: they make it possible to reduce the time between submission of articles by authors and the final availability of the article for readers. They also make it possible to drastically lower the cost for authors and readers. Open digital libraries can be accessed from both inside and outside the organization where they are running; and they offer formal and semi-formal literature. So, often an Internet connection and a login are all that is needed. Nevertheless, they still have some shortcomings: they often only focus on a particular field of research and they do not support adequate interaction among authors, among information consumers, and between the two groups.

In this paper we present the CYCLADES environment—a distributed and open collaborative virtual archive environment based on open archives, providing several services supporting individual researchers as well as communities of researchers. In the next section we will introduce the concepts of open archives and grey literature, which provide valuable sources for solitary work. We will analyse how users exchange information and knowledge and introduce communities to more adequately reflect the nature of human information and knowledge exchange. Finally, we will present the functionality and implementation of the CYCLADES environment.

2 Grey Literature and Open Archives

Today several initiatives support the fast and electronic exchange of formal scientific literature and grey literature. Grey literature (sometimes also spelled gray literature) is papers 'written to inform funding bodies about the results of research projects, to support grant applications, to inform rapidly a specific scientific community, to present preliminary results at conferences or as dissertations' and which are disseminated quickly, often in limited numbers, before or without the formal publication process

[9]. Often grey literature is semi-formal, between conversation and normal publication. A formal publication may follow later; but this formal publication is in general not publicly available. Grey literature can be seen as the counterpart of open source; the GrayLIT Network defines it as 'open source material that usually is available through specialized channels and may not enter normal channels or systems of publication, distribution, bibliographic control, or acquisition by booksellers or subscription agents' [10].

Several grey literature initiatives are under operation. The European Association for Grey Literature Exploitation (EAGLE) manages the System for Information on Grey Literature (SIGLE)—a bibliographic database covering grey literature in Europe from the fields of pure and applied natural sciences, technology, economics, social sciences and humanities. Other examples are Math-Net, which is a global electronic information and communication system for mathematics [11]; arXiv, which is an electronic archive of grey literature in the field of physics [29]; the Budapest Open Access Initiative, which provides support for free and unrestricted online availability giving authors and their works new visibility, readership, and impact [14]; and so forth.

In parallel to the grey literature initiatives so-called open archive initiatives have been launched. Already in the 1990s several universities started designing and implementing their own open protocols. Examples are the University of Michigan digital library project [5], the University of Stanford InfoBus project [3], or the Virginia Tech Sieve framework [28]. These open protocols allow fast and easy access from everywhere, but are in several occasions not fully compatible with each other.

So, today research results are often available within research communities, but not across boundaries. And these boundaries between disciplines reduce the ability of researchers to fully assess the work that has been accomplished and can lead to redundancy and to situations in which scholars are reinventing the wheel [1]. Clearly, with novel information and communication technology people can access, record, and organise information more easily. However, the organisation of science is still discipline-oriented and knowledge is grouped into subject domains that follow established lines of demarcation. Within these domains the items are broken down in even smaller units in order to isolate individual thoughts.

The value of discipline-specific publications is unquestioned, but additionally interdisciplinary work is still gaining momentum. Suleman and Fox argue that there has been a general desire for systems to be interoperable at the levels of data exchange and service collaboration and draw the conclusion that such interoperability requirements necessitate the development of standards such as the Dublin Core Metadata Element Set and the Open Archives Initiative's Protocol for Metadata Harvesting [25].

The Open Archive Initiative (OAi) was launched in October 1999 in an attempt to address interoperability issues among many existing and independent digital libraries. The OAi consists of a technical and organisational framework designed to facilitate the discovery of content stored in distributed e-print archives. It makes technical recommendations for archives that are easy to implement and that allow data from e-print archives to become widely available via its inclusion in a variety of end-user services [21]. Basically, the OAi metadata harvesting protocol supports the communication between different digital library components via a simple, yet powerful protocol. The individual components are digital libraries, which are modelled as networks of extended open archives, with each extended open archive being a source of data and/or a provider of services [25].

So, we now have a situation with several grey literature initiatives, open archives, as well as the OAi that aims at bridging the individual initiatives and archives. Yet, the question is, if this technological basis is enough for the exchange of information and knowledge among researchers. To address this question we did a literature study on human exchange of information and knowledge.

3 Exchanging Information and Knowledge

Hara and Kling [15] distinguish three types of knowledge that humans typically deal with: cultural knowledge and two kinds of subject-matter knowledge. Cultural knowledge includes information on how it is like to be a member of a certain community, including professional identity. Subject-matter knowledge can be book knowledge—that is, real facts—or practical knowledge—that is, the application of the book knowledge in practice. Both, cultural knowledge and practical knowledge are in general tacit knowledge, which is hard to identify and learn. Figure 1 visualises the different types of knowledge.

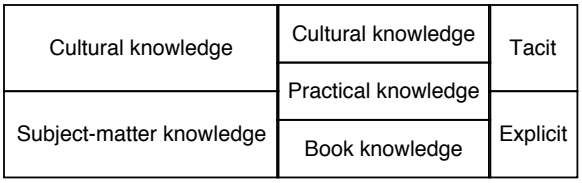

Figure 1. Three kinds of knowledge.

Berger and Luckman [4] examined the exchange of knowledge and the social construction of knowledge. They describe it as a process with three phases that can be identified during institutionalising knowledge: externalising knowledge refers to the exchange of knowledge among humans; objectifying knowledge means that the knowledge becomes an objective reality; and internalising knowledge means that individuals use the externalised knowledge during their socialisation.

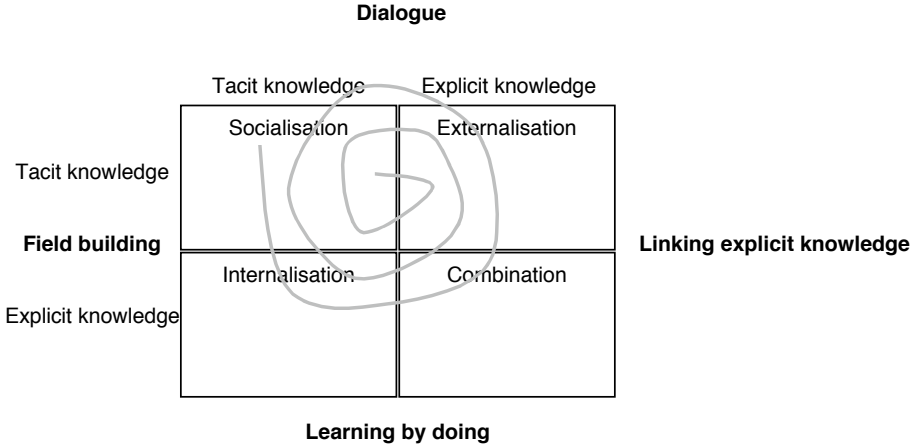

Figure 2. Nonaka and Takeuchi's knowledge spiral.

Nonaka and Takeuchi [20] have analysed the conversion of explicit and tacit knowledge. Explicit knowledge can be expressed easily; it is easy to formalise it and share it. It is created by experience, observation, and learning. Tacit knowledge, in contrast, is highly personal and difficult to express, formalise, and share. It is often subjective and based on insights, intuition, and emotion. Tacit knowledge can be technical (skills, know-how) or cognitive (mental models, perceptions).

The transition of knowledge can be described in a knowledge spiral (cf. Figure 2). We briefly describe the four quadrants: *Socialisation* is direct conveyance of tacit knowledge through shared experience. At the recipient's side tacit knowledge such as shared mental models and technical skills are generated. *Externalisation* is the process of articulating tacit knowledge into explicit concepts. For this purpose often metaphors, analogies, concepts, hypotheses, or models are used. Through metaphors complex systems and objects are explained by imaging another thing symbolically. *Combination* is the process of systematising concepts into a knowledge system. Thereby, different bodies of knowledge are synthesised. Typical combination activities are sorting, categorising, adding, and combining. *Internalisation* means embodying explicit knowledge in tacit, operational knowledge. Internalisation is the forth step completing a knowledge circle.

Internalisation is the basis for a new knowledge circle. Through socialisation, externalisation, and combination experiences can be internalised into the individuals' tacit knowledge bases—in the form of shared mental models or technical know-how—and become valuable assets. Likewise the tacit knowledge accumulated at the individual level needs to be socialised with other organisational members. This socialisation then starts a new spiral of knowledge creation.

In the spiral dialogue refers to the convergence of socialisation and externalisation; linking explicit knowledge refers to the convergence of externalisation and combination; learning by doing refers to the convergence of combination and internalisation; and field building refers to the convergence of internalisation and socialisation.

4 Communities

In the past in communities the described ways of information and knowledge exchange worked very well. The notion of community became famous in the 19th century. Until the middle of the 19th century the focus of the people was the local community, they were living and working there and their social interaction took place within the borders of the local community. With the industrial revolution, and increasing mobility and tele-communication, people were able to bridge geographical distances. Consequently, they increasingly had remote family and friends. Toennis [26] argues that in the old communal society (Gemeinschaft) personal relationships and face-to-face relations predominated, whereas in the society (Gesellschaft) rational will and carefully calculated conduct and behaviours are becoming increasingly dominant. In the communal societies understanding is a reciprocal sentiment, which binds the individual to a totality. In society individuals are basically alone and there is a tension between them; life is organised by regulations.

Today's online communities are somehow a mixture of Gemeinschaft and Gesellschaft; they are neither a familiar locale, nor an alienated metropolis [6]. Nevertheless, they offer and stimulate types of exchange and altruism that were quite typical for the communal societies. Bowker and Star [7] point out that the vast spreading of base technology such as personal computers and Internet connection in private households are both important prerequisites and stimulus for fundamental changes in the way people use and exchange information. They

emphasise that '[c]hanges in infrastructural networks such as transportation, information, and domestic technologies explain a great deal about other forms of social change and social relationships—they are not simply substrate, they are substance'. They continue by arguing that the substantive changes effected by digital library initiatives have significance both for science and far beyond it.

The term community is used in many different contexts with several different meanings, which more or less overlap. Bowker and Star [7, p. 11] point out that an exact definition of the term community is difficult and often controversy in literature, but 'there is general agreement that the sense of community rests on nontrivial, ongoing relations among people; some degree of shared knowledge, understandings, material objects, or conventional practices; and the idea that these two are not independent'. Virtual communities (also known as network communities or online communities) have several characteristics: they are technologically mediated and span traditional geographical limitations, they are persistent and exist for a mid- to long-term period, they offer multiple interaction styles such as informal and formal communication or peripheral and focused communication, they support some type of real-time interaction, and they support multi-users at the same time [12, 16, 18, 19]. Communities of practice are a special type of online communities. They are informal networks that support professional practitioners to develop a shared meaning and engage in knowledge building among the members. In communities of practice members construct knowledge socially as opposed to individually [15].

5 CYCLADES

The CYCLADES environment is based on these notions of information and knowledge as well as virtual communities.

5.1 Functionality

The functionality of the CYCLADES environment can be divided into four categories. Choo and colleagues [8] distinguish three different domains of functionality that information environments should provide: the information space, the communication space, and the collaboration space. Stenmark [24] extended this claim by a fourth domain: the awareness space. The information space gives users access to information in form of databases and documents. Ideally, it provides good functionality and support for information consumers as well as information producers. The awareness space explores both explicit links and tacitly expressed connections to hook up organisational members with information and people they might otherwise have missed. And it makes users aware of peers who have searched or browsed the same information or authored similar documents, which leads to an increased likelihood for community building, communication, and collaboration [24]. The communication space supports users with various channels for conversation and negotiation. It allows users to reflect together, thus facilitating understanding, which according to Schoen comes from reflection [23]. The collaboration space provides support for the actual cooperative work through workflows and shared project areas.

The CYCLADES environment supports all four domains. Figure 3 shows the architecture of the CYCLADES environment consisting of the archive environment and the service environment and maps the four domains to it.

The archive environment is composed of a large number of heterogeneous, multidisciplinary archives and supports interoperability between them. It is based on the Open Archive Initiative, which has been described earlier in this paper.

The service environment consists of a range of autonomous yet interoperable services, which support users with functionality for solitary research as well as for virtual communities. The *Mediator Service* (MS) integrates the functionality and the user interfaces of the individual services and acts as a registry for them. It manages the registration and login of users to the CYCLADES system. The *Access Service* (AS) provides an interface to the underlying metadata archives—it harvests, indexes, and retrieves metadata records from the underlying open archives. The AS allows users to register and unregister archives to and from CYCLADES and to edit archive information. The *Search and Browse Service* (SBS) supports searching records from the various collections, formulating and reusing queries, and browsing schemata, attribute values, and metadata records. The *Collection Service* (CS) supports the creating and editing of collections and manages the access by collection administrators. Collections partition the information space according to the users' interests, and make the individual archives transparent to the user. The *Filtering and Recommendation Service* (FRS) allows personalised filtering of queries and query results and provides recommendations of records, collections, users, as well as communities relevant to the users or communities. The FRS analyses a user's behaviour and data, generates a user profile describing the user's interests, and tries to provide information according to the user's interests. The *Collaborative Work Service* (CWS) provides a folder-based environment for storing and administrating metadata records retrieved from the archive environment, queries, collections, external documents, and annotations. It stores the users' private, community, and project folders. The CWS provides functionality for the management of the folders and their contents, for cooperation among community and project members, and for the management of recommendations. The *Rating Management Service* (RMS) is an internal component of the CWS that stores ratings and provides a query interface to other services of CYCLADES.

The areas surrounded by dashed lines in Figure 3 represent the four domains: the left-most area surrounded by round dots represents the information space; the middle area surrounded by square dots represents the awareness space; and the right-most area surrounded by a long dashes summarises the communication and collaboration space.

The *information space* provides functionality for solitary work. It allows easy, fast, and convenient retrieval of metadata records from the large, distributed, heterogeneous, multi-disciplinary and highly dynamic archives. Users can browse through data and through hypertext structures. In collections users can specify the scope as well as the format of future queries. The information space, furthermore, analyses users' online behaviour as well as folder structure and contents and generates user profiles. These user profiles are used to provide more adequate and personalised search results. The information space uses functionality from the MS, SBS, AS, CS, and FRS. It particularly aims at facilitating the exchange of book knowledge and the combination of explicit knowledge.

The *awareness space* provides users with information about other users and artefacts that they are not explicitly searching. Based on user profiles it provides users with recommendations about other users and communities with similar profiles. In our example in Figure 3 it recommends two users with similar profiles to each other. It also informs users about new incoming metadata records and collections. Furthermore, it collects all changes made in the folders of the users and sends daily activity reports giving a daily overview of the events and changes that happened during a day. The awareness space combines functionality from the MS and FRS. The information provided by the awareness space complements the other spaces—it provides additional hints and recommendations for solitary workers and stimulates communication and future collaboration. Through the recommendations and the daily activity report users get important practical knowledge about the activities of other users in the system. This timely shared experience about the activities of the others constitutes an exchange of cultural information and fosters socialisation within the different projects and communities that would normally only be possible in face-to-face cooperation.

The communication space and the collaboration space are based on the same service components and are represented within the same field in Figure 3. The *communication space* allows users to contact recommended users, to contact manager of recommended communities via email, and to exchange information with other members of the same project or community via threaded online discussions and annotations to metadata records in the folders. The communication space and the collaboration space are primarily based on the MS and CWS. Threaded online discussions that are held in folders and nested annotations to individual metadata records provide highly specific practical knowledge. These online dialogues and information in context facilitates reflection and externalisation of knowledge for authors, and reflection and internalisation of knowledge for readers.

The *collaboration space* provides the core functionality for Web-based folders and online communities. Users create private folders, community folders, as well as project folders and add subfolders and documents to them. In private and community folders users can store and manage metadata records and query results; in project folders they can additionally have other

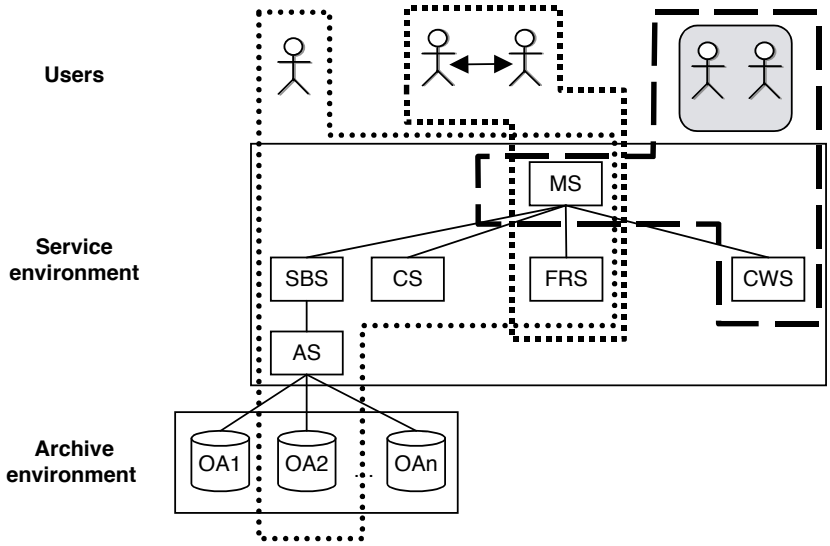

Figure 3. CYCLADES environment including archive and service environment as well as users.

types of documents (e.g., PDF-files, slides, text files). Only the owner of a private folder can see its content. The members of communities and projects and seen, access, and change the contents of the respective community and project folders. They can rate documents on a scale from 'poor' to 'excellent'. Event icons that are automatically attached to folders and documents present information about recent changes at a glance. Users can join projects by invitation. They can join open communities by registering to the community, and become a member of a closed community by getting an invitation of the community manager. Figure 4 shows a screenshot of the collaboration space of CYCLADES.

The online communities supported by the collaboration space allow users to easily share book knowledge and explicit practical knowledge—for authors it is easy to set up community folders and project folders, and collaboration spaces stimulate information sharing and personal dialogues among users.

5.2 Implementation

The CYCLADES environment is based on a highly distributed software architecture. The open archives are distributed at individual organisations; they are accessed via the open archives initiative protocol for metadata harvesting OAi-PMH [22]. The services of the service environment mainly communicate via the MS; XML-RPC is used as a communication protocol. XML-RPC is a simple protocol for implementing cross-platform, distributed applications. It encodes messages in XML and communicates via HTTP [27].

The individual services run totally independent from each other at different sites, using individual

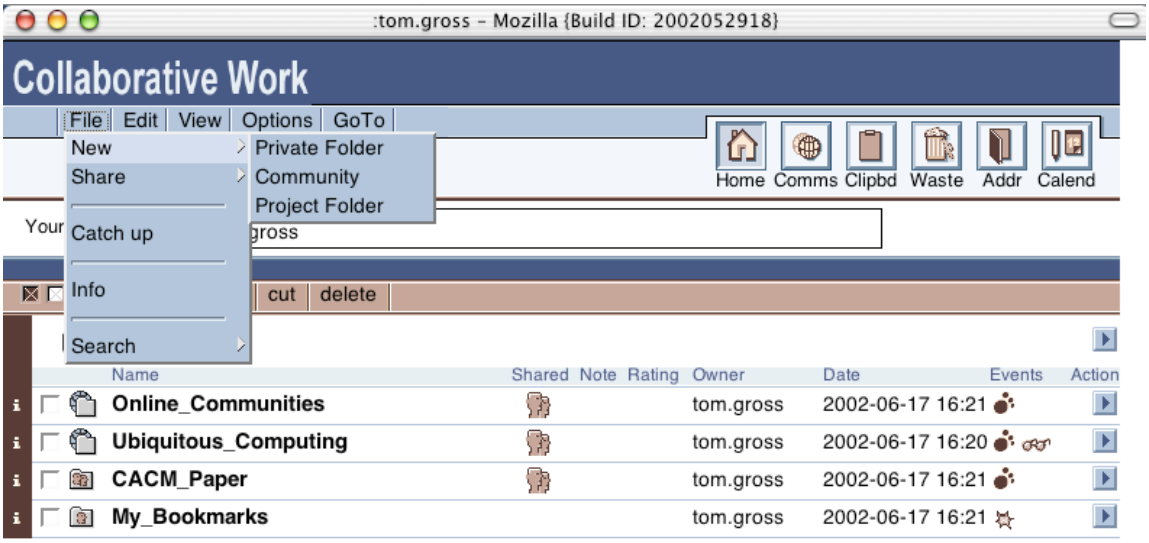

Figure 4. Collaboration space of CYCLADES.

to invite other users, and to publish information by storing query results or uploading documents from their local computer. The members of the respective project and community can than easily extend and update a shared knowledge space.

Through this combination of functionality from the information space, the awareness space, the communication space, and the collaboration space the evolution of knowledge in the sense of Nonaka and Takeuchi's knowledge spiral is facilitated. Both the exchange and sharing of mental models among individual users as well as the creation of organisational knowledge are supported. The information space provides explicit knowledge and allows users to link existing knowledge and to have learning by doing experiences; the awareness space facilitates field building; and the communication

environments and tools. The MS, for instance, was implemented based on an Apache Web-server with Tomcat in combination with an Oracle8i database and JDBC. The AS also uses and Apache Web-server with Tomcat, but combines it with a Postgres database as well as Java and Perl. The SBS only needs an Apache Web-server with Tomcat. The CS uses a MySQL database and Java. The FRS uses BerkeleyDB and Java. And, finally, the CWS uses an Apache Web-server and Python.

The user interaction with the CYCLADES environment is based on HTTP and HTML; so CYCLADES users only need a standard Web-browser without any extensions. The CYCLADES environment can, therefore, be used on any computer with any operating system—if Web-access and a Web-browser are available. This platform independence was one of the results of a study of future users we did with an online

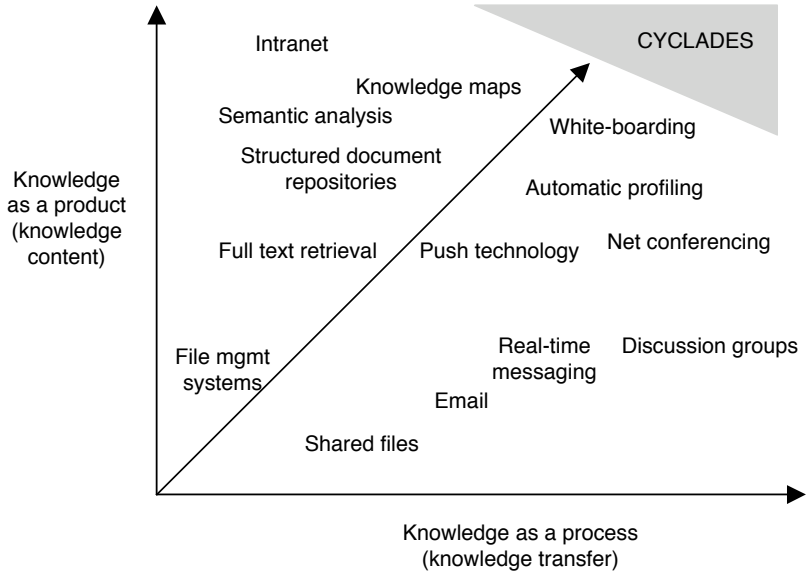

Figure 5. The process and product approaches in KM software.

questionnaire before we started developing the CYCLADES environment [13].

6 Related Work

Mentzas and colleagues [17] did a study on several systems dealing with explicit and tacit knowledge. The authors emphasise two perspectives on knowledge management: product and process. The product perspective refers to explicit knowledge and sees knowledge as a thing that can be located and manipulated as an independent object. From this perspective knowledge can be captured, distributed, measured, and managed. Consequently, systems supporting explicit knowledge are typically centred around the management of documents, including best-practice databases, lessons-learned achieves, and case-bases. The process perspective refers to tacit knowledge and emphasises the aspect of knowing and embodiment of knowledge in human experts. Here knowledge management aims at stimulating and supporting social communication by cooperation technology. Examples of such cooperation technology are email, video-conferencing, or shared workspaces. Figure 5 shows examples of technology developed from the two perspectives.

Most systems are either good at supporting knowledge content or supporting knowledge transfer. Virtual community systems and especially the CYCLADES environment integrate the two perspectives and provide support for knowledge as a product and for knowing as a process.

The CWS is based on the BSCW shared workspace system [2]. The BSCW system provides is a Web-based system centred around shared workspaces. It provides functionality for creating workspaces and sub-folders, uploading documents, access management to the workspaces and their contents, event services and daily activity reports for informing users about each other, and so forth. The CWS and the CYCLADES environment go beyond the BSCW system. In its current state, the BSCW does not have specific folder-types, does not provide open workspaces or folders, does not analyse the folder structure or the behaviour of its users, does not provide recommendations, does not offer connectivity to open archives or any other application programming interface, and so forth.

7 Conclusions

In this paper we have motivated and discussed digital libraries and open archives supporting the exchange of formal as well as grey literature. We have analysed the exchange of information and knowledge among humans and suggested online communities to complement the functionality of existing digital libraries and open archives. We have introduced the CYCLADES environment providing a range of services on top of the open archive environment in order to support efficient and effective exchange of information and knowledge among individual researchers and communities of researchers.

So far, the individual services of the CYCLADES environment have been implemented and integrated into the overall system. The functionality has been tested and the CYCLADES environment has been used by the project partners. So, we have some initial feedback concerning the use of the system. However, the

deployment of the environment to the actual users, a thorough evaluation with the users, and some potential refinements and improvements have yet to be done.

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