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Collaborative trails and group profiling within an e-Learning environment.

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Summary

This deliverable focuses on collaborative trails produced by groups of learners and the support that can be provided for them. We begin by reviewing the theoretical and psychological background to collaborative learning and looking at the kinds of support that computers can give to groups of learners working collaboratively. We then look more deeply at some of the issues in designing environments to support collaborative learning trails and at tools and techniques, including collaborative filtering, that can be used for analysing collaborative trails. We then review the state-of-the-art in supporting collaborative learning in three different areas – experimental academic systems, systems using mobile technology (which are also generally academic), and commercially available systems. The final part of the deliverable presents three scenarios that show where technology that supports groups working collaboratively and producing collaborative trails may be heading in the near future.

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TRAILS

The World-Wide-Web has had a major impact on enabling large, diverse and geographically distributed communities of learners to access Technology Enhanced Learning. Systems combining technological learning tools with personalisation that caters for individual styles and learning preferences have the potential to radically alter the landscape of learning.

A recent development has been in the use of learning objects (LOs) – cohesive pieces of learning material that are usually stored in a repository, allowing teachers and learners to search for LOs of interest to them. Learners engage with LOs in the form of trails – time-ordered sequences of LOs.

Examples of LO trails are:

(i) a school-child navigating through course materials,
(ii) a learner navigating through the literature on a subject, or
(iii) a visitor navigating through a museum.

By following and creating trails, the learner navigates through a space of LOs creating a personal trail that can be evaluated and accessed in a structured manner. These directly observable LO trails are related to learners' non-observable cognitive trails.

Trails are the subject of the *Personalised and Collaborative Trails of Digital and Non-Digital Learning Objects* project (TRAILS for short). TRAILS is a one-year Jointly Executed Integrating Research Project within the Kaleidoscope Network of Excellence, an IST project funded under EU FP6. At the core of the programme is the view that trails can provide structure to learners' information space and thus can assist them in achieving their objectives. TRAILS brings together experts from computer, social and cognitive sciences in order to:

- generate a framework for describing, classifying and understanding trails of LOs;
- study the pedagogical and cognitive aspects of personalised trails;
- investigate the types of individual need (personalised, individualised, collaborative, context dependent and content dependent) which learners have in terms of trails;
- evaluate and assess methods, which cater for learner needs;
- produce a schema for representing these learner needs in a specific user profile;
- produce a schema for integrating learner needs with appropriate LO metadata;
- design a system for mapping the patterns of trails created by learners and for producing a training needs analysis for targeting future learner experiences;
- investigate different types of LOs and how they may form trails;
- specify the requirements which trail-support places on e-Learning systems;
- work towards a standard for LOs in trails which is compatible with current standards.

Executive summary

This is the second deliverable of Workpackage 4 of the TRAILS project. The objectives of Workpackage 4 are as follows:

- To study what support is needed for individuals and groups of learners within an e-learning system.
- To study what profiling information is needed for personalisation within an e-learning system.
- To investigate how personalised and collaborative trails emerge in an e-learning system.
- To investigate how personalisation and collaborative filtering technology can assist in mining and presenting such trails.

This deliverable focuses on the aspects of these objectives that are related to collaboration within groups of learners, and hence collaborative trails. We begin by reviewing the theoretical background to collaborative learning (Section 2) and looking at the kinds of support that computers can give to groups of learners working collaboratively (Section 3). We then look more deeply at some of the issues in designing environments to support collaborative learning trails and at tools and techniques, including collaborative filtering, that can be used for analysing collaborative trails (Section 4). We then review the state-of-the-art in supporting collaborative learning in three different areas – experimental academic systems (Section 5), systems using mobile technology (which are also generally academic) (Section 6), and commercially available systems (Section 7). The final part of the deliverable presents three scenarios that show where technology that supports groups working collaboratively and producing collaborative trails may be heading in the near future (Section 8).

The first objective above is addressed by Sections 2 and 3, which look in general terms at why groups of collaborative learners need support and the kind of support they need. The second objective is covered by the first deliverable in this Workpackage – D22.4.1 on Personalised trails – and is not addressed directly in this document. The third and fourth objectives are addressed (for collaborative trails) by Sections 4-7, which look at a number of real systems to see how collaborative trails emerge, and also look at technologies and techniques for analysing such trails. Section 8 finally brings all of these aspects together to describe scenarios that illustrate the support that learners need, the collaborative trails that they create and how these can be usefully analysed.

1 Introduction

In recent years in the field of education there has been much attention given to work around Computer Supported Collaborative Learning (CSCL). The basic idea is that learners profit from working together and learning together, as this invokes a deeper learning, and computers and the Internet provide just the tools needed for communication and collaboration to enable this kind of learning.

The idea of collaborative trails was introduced in Kaleidoscope deliverable D22.2.1 (Schoonenboom et al., 2004), an earlier deliverable from the TRAILS project. This deliverable seeks to explore further the different forms that collaborative trails can take, how such trails can be usefully analysed, and how systems can support learners in creating and reflecting on the trails they take. It should be noted that not all collaborative trails come from collaborative learning – collaborative trails can emerge from a collection of individual paths through learning materials of learners who never meet or communicate with one another at all. The focus in this deliverable, however, is mainly on the trails created by learners when they work together on some common learning goal, in a CSCL context.

The document is structured as follows: Section 2 gives a brief overview of the theoretical background to the development of CSCL, looking at constructivism, cooperation and collaboration. Section 3 looks at ways in which these theories can be put into practice in a computer supported environment. Three pedagogical models for achieving this are considered, and the section concludes with an assessment of how trails can be supported in such scenarios. Section 4 then moves on to look in more detail at the design of environments to support CSCL and at the techniques of collaborative filtering and conversational analysis that can be used to recommend items to learners and to help reflection on collaborative activity respectively. Section 5 reports on some of the existing research systems and state-of-the-art collaborative learning systems currently available, and categorises them into a taxonomy proposed by Jermann et al. (Jermann, Soller and Muehlenbrock, 2001), and concludes with a look at some of the main ongoing research issues in collaborative learning. Section 6 considers the new dimension added to collaboration via technology when the technology is mobile, and considers the occurrence of collaborative trails in mobile learning. Section 7 takes a look at how much support for collaboration is provided by current commercial e-learning systems, and we conclude in Section 8 by describing some learning scenarios that show where we think support for collaborative trails may be going in the next few years – they are futuristic, but quite possible with the technologies being currently developed.

2 The social dimension of learning

2.1 Constructivism

In the theories of constructivism, learning is perceived as an *active*, *constructive* process during which the learner builds new knowledge from previous knowledge. Social constructivist theories of learning are heavily influenced by the work of Vygotsky, who developed a complete theory of education and learning that views learning as strongly influenced by social, cultural, and historical factors. In his view, learning is something that the learner actively does, rather than something that is done to the learner – understanding new knowledge is a process involving the transformation of the learner's mental representations. Moreover, learning is something that learners do together, under the direction of a facilitator. Of course, learners can learn by themselves, but this doesn't imply that they learn alone – learning is always situated in a given space, time, and social environment. The environment includes both material components (documents, tools but also the classroom, resource centre or a learner's home) and human components (for instance other learners, fellows, teachers, educators and parents).

Many current educational theories (e.g. cooperative learning, project-based learning, peer coaching, and the role of language as a mediator of learning) are related in important ways to ideas first developed by Vygotsky almost seventy years ago. However, education today has available a range of technologies that could not even have been imagined in Vygotsky's days. Harvey and Charnitski (2003) identify the relevance of Vygotsky's theories and their potential usefulness as guides to effective educational practice in the context of today's technology-rich educational environments, with an emphasis on distance learning.

According to Vygotsky, concept formation is an ongoing interaction between the concrete and the abstract dimensions, where engagement in concrete activities supports the formation of mental models, which he summarised in four foundational ideas: *learning as a socio/historical/cultural activity, the role of language, the zone of proximal development, and scientific and spontaneous concepts*.

Current and emerging technologies for distance education make it possible for learning to be distributed among learners who are separated both in space and time, which raises the questions in relation to the applicability of Vygotsky's work:

- Is there a “virtual zone of proximal development” that would help educators to design and implement synchronous or asynchronous learning activities?

- Do the written communications in online discussions and chat serve the same function as “speech”?
- What is the socio/cultural/historical context of a group of learners who are widely distributed geographically and even culturally?

According to the constructivist view, learners control and are responsible for their own learning processes. However, this does not imply that the teacher’s role is decreased – on the contrary, the teacher is responsible for organising the conditions for effective learning to take place. In this sense, teaching is creating, designing and organising learning situations. Design of constructivist learning environments is important in enabling the effective use of collaboration. Learners share information to collaboratively construct socially shared knowledge. Applications such as computer conferencing, chat lines, newsgroups, and bulletin boards promote conversation and collaboration and assist meaningful learning. The use of these tools helps facilitate discussion and sharing of ideas amongst learners when they are addressing the same goals. In this way peers are identified as resources rather than competitors.

We believe that the paths in space and time taken by learners through the social and physical environment can be considered as complex learning trails. Similarly, the “forward movement” of the zone of proximal development as a learner progresses in their learning represents one aspect of the “cognitive trail” of the learner. Modelling or recording these complex trails in their entirety would be impossible, but (as we will see in this deliverable) meaningful sections of these complex trails can be recorded, modelled and manipulated in order to support learning.

2.2 Cooperation and collaboration

Cooperation and collaboration are synonyms, meaning to act or work jointly for a common aim, however they have different nuances of meaning in the literature. Roger and Johnson (2002) define cooperative learning as a relationship in a group of students that requires positive interdependence, individual accountability, interpersonal skills, interaction and processing. Strijbos (2000) concludes a distinction between “co-operative learning” and “collaborative learning” based on the amount of pre-imposed structure, task-type, learning objective and group size, and develops a classification-model to illustrate not only differences between both perspectives, but also various types of computer support for group-based learning.

Several definitions of collaborative learning can be found in the literature:

(a) Collaborative learning is a reculturative process that helps students become members of knowledge communities whose common property is different from the common property of the knowledge communities they already belong to (Bruffee, 1993).
(b) Collaborative learning is the mutual engagement of participants in a coordinated effort to solve problem together (Roschelle and Behrend, 1995).
(c) Collaborative learning is the "acquisition of knowledge, skills or attitudes that take place as a result of people working together to create meaning, explore a topic or improve skills" (Graham and Scarborough, 1999).

Followers of Vygotsky have tended to see collaboration as scaffolding and appropriation – scaffolding by a more expert peer, and appropriation by a less expert peer (Forman and Cazden, 1985; Newman et al., 1989). Piaget and his followers tended to see collaboration as producing productive individual cognitive conflict – disequilibrium drives conceptual change (Doise and Mugny, 1978; Perret-Clermont, 1980; Piaget 1932). The Vygotskian account tends to portray asymmetric roles, whereas the Piagetian account emphasises the benefits of conflict. In contrast, the "collaboration as convergence" viewpoint emphasises mutual construction of understanding.

Examples of collaborative learning include:

- Group Investigation
- Problem-Based Learning
- Project-Based Learning
- Expeditionary Learning

One of the main questions for the design of computer-based learning environments is whether such participatory discussion methods can be effectively orchestrated at a distance, and if so how might this be done.

The next section investigates how ideas about constructivism, collaboration and collaborative learning can be supported in computer-supported environments, and considers three distinct pedagogical models that incorporate these ideas.

3 Computer supported collaborative learning (CSCL)

Computer Supported Collaborative Learning (CSCL) as a domain for study and investigation has emerged from several theories, including constructivism as discussed in the previous section. Communication and collaboration are essential elements when introducing a constructivist approach to learning, and computers and computer networks provide tools for extended communication and collaboration between learners. Theoretical references include the “community of learners” model (Brown, et al. 1993), in particular the notions of constructionism, as defined by Papert (1991), and of “distributed” and “situated” cognition (Lave, 1991). The communication theory applied to the mediation of computer software (Clark and Brennan, 1991) integrates this model. CSCL focuses on the use of technology as a mediational tool within collaborative methods of instruction (Koschmann, 1994).

What should be borne in mind is that CSCL is not the same as e-learning: E-learning is the delivery (by electronic means) of educational content to learners who are not necessarily in the same place at the same time. On the other hand, CSCL can be done by teachers and learners who are together at the same place and time. For this same reason, CSCL is not the same as computer assisted instruction. Central to the idea of CSCL is the collaboration and communication part of it, not the computer part – the computer is only there to facilitate collaboration.

In general, five different categories of CSCL can be distinguished:

1. The first type of CSCL occurs in small groups, behind the computer screen. The communication is face-to-face, and the computer serves only as the tool that pupils work on.
2. The second type of CSCL is face-to-face collaboration within the classroom, together with the help of a networked computer environment. Often a shared workspace, or a networked knowledge-building environment is an element of this type of CSCL.
3. The third type of CSCL is where pairs (or groups) of learners in one classroom collaborate with pairs (or groups) in another classroom over the web.
4. The fourth type of CSCL is when most of the communication and collaboration is done through the web, but there is also a substantial amount of face-to-face communication. This is often seen in higher education.
5. The fifth type of CSCL is where all the communication is done through the web, and there is (practically) no face-to-face communication and collaboration.

In the following subsections we present different pedagogical models that are based on the constructivist approach. They lean heavily on the work done within the IST-projects ITCOLE[1] and Celebrate[2].

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[1] http://www.euro-cscl.org

[2] http://celebrate.eun.org

3.1 The jigsaw model

A concrete and simple approach for applying CSCL in the classroom is the “jigsaw model”. (Aronson et al., 1978; Clarke, 1994; Slavin, 1995). The jigsaw model is based on shared responsibilities within a group – a classroom of pupils is divided into smaller groups, and each group learns a specific part of a bigger task. Each individual becomes an expert in the task at hand and after learning this expert task the groups mix in such a way that each group now has one expert for each of the different tasks. These groups then have to learn the whole picture – the goal of each pupil now is to teach the other members of the new group the task he is an expert in.

The model invites the pupil to be a teacher. Learning a certain task may not be that difficult, but to learn something with the goal of being able to teach it to others requires higher order skills, and a better mastery of the task or learning subject. This model also enables group discussion and practice-by-doing. In addition pupils learn how to switch between different roles.

3.2 The progressive inquiry model

In the literature on educational research, there are several models for *inquiry learning* in primary and secondary level education. A number of them have been developed to model and facilitate inquiry in natural sciences, e.g., scientific visualisation technologies to support inquiry-based learning in the geosciences (Edelson et al., 1999), or project-based science and laboratory work (Krajcik et al., 1998). Several researchers have proposed that in order to facilitate higher-level processes of inquiry in education, cultures of schooling should more closely correspond to cultures of scientific inquiry (Brown et al., 1989; Carey and Smith, 1995; Collins et al., 1989; Perkins et al., 1995). This includes contributing to the collaborative processes of asking questions, producing theories and explanations, and using information sources critically to deepen one's own conceptual understanding. Scardamalia and Bereiter (1994, 1999) have proposed in their *knowledge building* theory that schools should be restructured towards knowledge-building organisations, in which students and teachers participate in the construction of collective knowledge as in professional research groups where the object of activity is solving knowledge problems.

By synthesising these demands, Hakkarainen and his colleagues in the University of Helsinki (Hakkarainen et al., 2001) have developed a model of *progressive inquiry* as a pedagogical and epistemological framework that is designed to facilitate expert-like working with knowledge in the context of computer-supported collaborative learning (CSCL). It is primarily based on Scardamalia and Bereiter's (1994) theory of knowledge building, on the interrogative model of scientific inquiry (Hintikka, 1985; Hakkarainen and Sintonen, 2002), and on the idea of distributed expertise in a community of learners (Brown and Campione, 1994). The model has been implemented and studied in various educational settings (Hakkarainen et al., 1998; Lipponen, 2000; Rahikainen et al., 2001; Lakkala et al., 2002).

In progressive inquiry, students' own, genuine questions and their previous knowledge of the phenomena in question are a starting point for the process, and attention is drawn to the main concepts and deep principles of the domain. Although students are learning already existing knowledge, they may be engaged in the same kind of extended knowledge-seeking processes as scientists and scholars. From a cognitive point of view, inquiry can be characterised as a question-driven process of understanding. Without research questions there cannot be a genuine process of inquiry, although nowadays at schools information is frequently produced without any guiding questions. The aim is to explain phenomena through a question-answer process, in which students and teachers share their expertise and build new knowledge collaboratively with the support of information sources and technology.

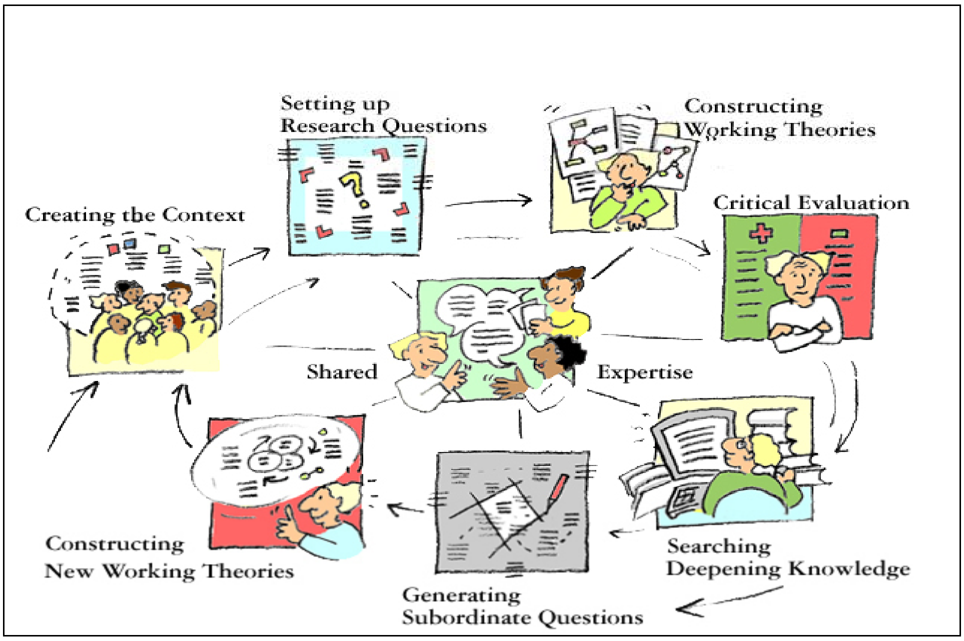

Figure 1: The Progressive Inquiry Model

The progressive inquiry model specifies certain epistemologically essential elements that a learning community needs to go through (although the relative importance of these elements, their order, and content vary a great deal from one setting to another). A group of learners goes through a cycle of seven stages, thus building distributed expertise in their group. The cycle is shown in Figure 1, and consists of:

(1) *Creating the Context*: The context for the project is jointly created, anchoring the problems being investigated to conceptual principles of the domain and establishing the learning community by joint planning and goal-setting;
(2) *Setting up research questions*: An essential aspect of progressive inquiry is for students to generate their own problems and questions to direct the inquiry;
(3) *Constructing working theories*: Generation and sharing of students' own hypotheses, theories, or interpretations of the phenomena being investigated;
(4) *Critical evaluation*: Assessment of strengths and weaknesses of the different theories and explanations produced;
(5) *Searching deepening knowledge*: Exploration of diverse sources of information and a comparison of intuitively produced working theories with well-established expert knowledge – this tends to make weaknesses of the community's conceptions explicit;
(6) *Generating subordinate questions*: Transformation of the initial big and unspecified questions into subordinate (and frequently more specific) questions advances and refocuses the process of inquiry;
(7) *Developing new working theories*: New questions and the scientific and/or expert knowledge give rise to new theories and explanations. The summaries and conclusions of a community's inquiry should be published;
(8) *Distributed expertise*: When the stage of new theory is reached the cycle starts over again. All seven phases of the process should be shared among participants, usually by using collaborative technology. Within the group of learners this model leads to shared expertise.

Although scientific inquiry is a prototypical example of progressive inquiry, corresponding processes are frequently observed in the humanities and many other kinds of cultural activities. One has to engage in a process of inquiry whenever there is a problem that cannot be solved with available knowledge.

3.3 Problem-based learning

Problem-based learning is a practice-oriented pedagogical model, in which students develop their expertise on the content area in question by working with cases and problems that represent real-life situations (authentic problems) (Savin-Baden, 2000).

It is important to notice that problems are not "exercises" or ready-made questions, as problems are sometimes thought of, for example, in mathematics.
Savin-Baden (2000) defines three essential conditions for problem-based learning:

1. It concentrates on constructing a curriculum based on problems, to support a broad, cross-curriculum approach, and to support learning of cognitive skills instead of specific subjects;
2. It is supported by a tutor’s guidance, work in small groups, and active learning;
3. The outcomes are the development of skills and motivation, and the ability for life-long learning.

The outcomes of problem-based learning are anticipated to be:

- Increasing expertise of the content area;
- Problem-solving skills and the ability to solve new and challenging problems;
- Good metacognitive skills, such as the ability for self-reflection;
- Higher order cognitive skills, such as decision making, critical and creative thinking;
- The ability to connect declarative and procedural knowledge.

The two main elements of the model are the problem descriptions and the problem-solving process.

Problems form the starting point for the studies. A problem might be, for example, a statement, a simulated patient complaining of some symptoms, or a description of a phenomenon. It might also be an open question without one single answer (typically a why- or a how- question). Problems consist of authentic descriptions, which include all essential information of the situation/case, as in real life – i.e. not just ready-made summaries or exact references to textbooks. A problem description in medical studies, for example, might include a patient simulation, descriptions of symptoms, results of laboratory tests and background information on the patient.

Students are organised to work in study groups. In the group discussion, they define the study problem based on the description of phenomena, events or cases that have a relationship with each other. The description is the basis for students' collaborative discussion and inquiry; it is essential that they formulate the study questions themselves instead of getting ready-formulated questions. Because students have these complex and authentic descriptions, they choose themselves what they regard as essential for defining their study problem.

Problem solving is the key activity for learning in the problem-based learning approach. Problem solving is group work – the students learn in a group to divide the problem into sub-problems, to formulate hypotheses, to activate the previous knowledge and to reflect on their work (Moust et al., 2001). This can be helped by organising group work with formal roles of a chairman and a secretary.

The process has five different phases: problem identification, data collection, assessment, recommendation and evaluation of the solution (Savin-Baden, 2000). The cycle can be repeated several times in order to solve the original problem.

3.4 Supporting TRAILS in CSCL

Several types of computer support are involved in CSCL. Jermann, Soller and Lesgold (2004), following Dillenbourg (1999), make a distinction between computer support for structuring collaboration, which is done before collaboration takes place, and computer support for regulating collaboration while it is taking place. They distinguish between three types of systems for structuring collaboration:

1. The first type consists of standard productivity and communication tools, such as word processors, spreadsheets, databases, email and messengers, which might be brought together in a virtual learning environment.
2. The second type of structuring tool is specifically designed to enhance the quality and effectiveness of collaborative interactions. Examples include the use of sentence openers in discussions and shared visual representations such as concept maps.
3. The third type is the collaboration script, the predefined scenario.

Standard productivity and communication tools

Unsurprisingly, standard productivity and communication tools are useful to the pedagogical scenarios described above. Most relevant to the context of CSCL is the use of digital learning environments. Two characteristics of digital learning environments make them especially fitting for supporting CSCL. Almost all digital learning environments offer the possibility of creating private, protected workspaces for subgroups within one class. In these workspaces the members of one subgroup can discuss with each other and share materials that are not accessible to people outside the subgroup. Secondly, digital learning environments make it possible for members of a subgroup work together at a distance. Learners can access the private workspaces and all other materials that belong to a course from almost every computer that has an Internet connection. Since all three scenarios mentioned above involve small group work, these benefits of digital learning environments are relevant to each of them.

Structuring tools

Computer support systems for regulating interaction take as their input the collaborative behaviour of the participants. From this behaviour, they extract information on some collaboration indicators, such as the symmetry of participation, the quality of knowledge sharing and level of participation. This information might be used in remedial actions, such as signalling a breakdown in knowledge building, or they might be presented as awareness signals to the participants, so that participants come to know the presence, level of activity, and/or preferred learning objects of other participants.

Within the ITCOLE project, computer tools have been developed for both structuring and regulating collaboration. The learning environment Synergeia, developed within the ITCOLE project, makes use of 'knowledge types', which are based in the famous 'thinking types' of Scardamalia and Bereiter (see Scardamalia and Bereiter 1992). The knowledge types of Synergeia bear labels such as Problem, Explanation, and Summary, which students have to attach to their contributions. The 'MAPTOOL' within the environment makes possible the joint construction of concept maps.

Computer support for collaborative trails involves tools for both structuring and regulating collaboration. With respect to trails, the most important trail type in CSCL is the discussion trail. In terms of the TRAILS taxonomy (Schoonenboom et al., 2004), tools that structure collaboration are *graphs* – both the *mind map* and the *learning environment*. The *learning environments* that are involved are *compound learning environments*, in which learners can choose which learning objects to visit. Tools that regulate collaboration are tools that act mainly on *discussion trails*.

Collaboration scripts

The creation of trails is supported by structuring tools, which are mainly collaboration scripts. One example is the IMS Learning Design (IMS-LD). Lejeune and David (2004) have demonstrated how trails can be plotted and effected within IMS-LD. In IMS-LD collaboration is supported by defining activities and clustering these into acts, by assigning roles to activities and participants to these roles. This makes it possible to design different learning routes for each individual role, and thus for each group of learners or for each individual learner that plays that role. IMS-LD thus makes it possible to orchestrate collaboration, e.g. to let participants part and perform the activities specific to their respective roles, and let them come together to discuss their results. Furthermore, IMS-LD allows for each activity to be checked for completion, and for the next activity that should be performed upon completion to be suggested, thus allowing for further personalisation.

Tools for regulating collaboration are mainly tools that analyse discussion trails. A first example is EPSILON (Jermann, Soller and Lesgold 2004). In the EPSILON system, students use sentence openers such as ‘I think’ and ‘I agree’ to identify to the system their underlying intention. The system contains models of effective and ineffective knowledge sharing, which are essentially effective and ineffective trails. If the system detects ineffective knowledge sharing, remedial actions can be undertaken.

Blake (2004) provides an example of the use of structuring tools that analyse discussion trails. In the user studies conducted by Blake, propositions within discussion messages were classified into categories such as ‘adds new info’, ‘agrees with others’, ‘poses solution to controversy’, ‘disagrees’ and ‘seeks clarification’. This type of information provides evidence of collaborative work, documents student actions and conveys information to participants about other participants.

Collaboration scripts are also very relevant to the pedagogical scenarios described above. All three of them involve both roles and distinctive phases, which are the main ingredients of scripts. Digital learning environments can support working in phases, by assigning different workspaces to different phases. They can also support role division, by assigning different activities an/or resources to learners with different roles.

The next section looks in more detail at the design of environments to support CSCL, including the work done in the Colabs project, and goes on to discuss some of the techniques and tools that can be applied in such environments: collaborative filtering, which allows the recommendation of content within groups of similar users, and conversational analysis, which helps analysis of and reflection on collaborative activity.

4 Designing virtual environments for collaborative learning

Effective design begins not with the virtual environment itself, but by identifying existing functioning groups and then determining how to best use technological infrastructures to support their continued growth. We need a good understanding of what constitutes “community” in ways that are especially relevant for learning, and to investigate the difficulties of designing for the emergence of a community online (Barab, 2003).

Jonassen (1999) set up a model for designing Constructivist Learning Environments (CLEs) on the Web. The essential components are shown in Figure 2.

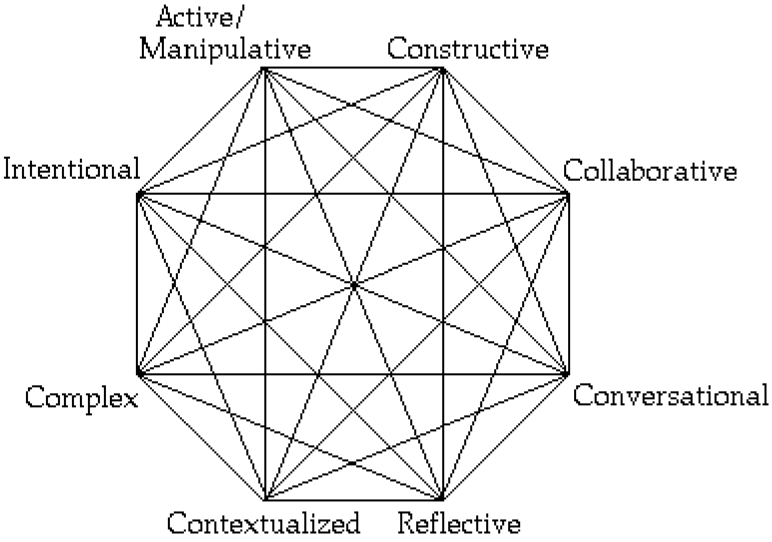

Figure 2: The essential components of a CLE[3]

The essential focus of any CLE is the ***problem*** or project that learners attempt to solve or resolve – it constitutes the learning goal.

- *Problem context*: CLEs must describe the contextual factors surrounding the problem.
- *Problem representation*: must be interesting, appealing, and engaging.
- *Problem manipulation:* learners must affect the environment to engage in meaningful learning – e.g. by constructing a problem, manipulating parameters, making decisions.
- *Related cases:* help learners to understand issues implicit in the problem representation.
- *Information resources:* learners can select information to construct their mental models and formulate hypotheses that drive the manipulation of the problem space.
- *Cognitive knowledge construction tools:* generic computer tools to support learners in a variety of cognitive processing tasks, e.g. to visualise (represent), organise, automate or supplant information processing.
- *Conversation and collaboration tools:* support computer-mediated communication among communities of learners, providing access to shared information and shared knowledge.
- *Social/Contextual support:* support for learning activities such as exploration, manipulation and articulation by modelling, coaching, and scaffolding these activities:
    - *Modelling:* modelling of the performance behaviour or cognitive process, by demonstration of how to perform the activity or articulation of the reasoning;
    - *Coaching:* motivation, performance analysis, providing feedback and provoking reflection and articulation of what was learned;

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[3] From http://tiger.coe.missouri.edu/~jonassen/courses/CLE/

- *Scaffolding:* provide temporary frameworks to support learning and performance beyond the students' capabilities.

The problem itself drives the learning, so it is important to provide interesting, relevant, and engaging problems to solve. CLEs can also foster and support Communities of Learners, which emerge when students share knowledge about common learning interests.

Some examples of collaborative on-line environments are *Inquiry Learning Forum*[4], an on-line community of practice for grade 5-12 mathematics and science teachers, *Tapped In*[5], which intends to support the online activities of a large and diverse community of educational professionals, and *CSILE* (Computer Supported Intentional Learning Environments)[6], which functions as a "collaborative learning environment" and a communal database, with both text and graphics capabilities. This networked multimedia environment lets students generate "nodes," containing an idea or piece of information relevant to the topic under study. Nodes are available for other students to comment upon, leading to dialogues and an accumulation of knowledge. Students have to label their nodes in order to be able to store and retrieve them; over time, they come to appreciate the value of a precise, descriptive label. In addition to receiving writing practice as they create their own nodes, students get practice reading the nodes generated by others (Scardamalia and Bereiter, 1994).

4.1 Tools for collaboration

Computer Mediated Communication (CMC) is the process by which people create, exchange, and perceive information using networked telecommunication systems that facilitate encoding, transmitting, and decoding messages. "CMC, of course, isn't just a tool; it is at once technology, medium and engine of social relations. It not only structures social relations, it is the space within which the relations occur and the tool that individuals use to enter that space". (Jones, 1995).

One of the main distinctions that has been made in CMC is between *synchronous* (real time) and *asynchronous* (delayed time) communication. Forms of asynchronous communication include:

- email
- discussion group (e-mailing lists, newsgroups)
- discussion forum (message board or discussion board).

Forms of synchronous communication include:

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[4] http://ilf.crtl.indiana.edu

[5] http://www.tappedin.org

[6] http://www.ed.gov/pubs/EdReformStudies/EdTech/csile.html

- instant messaging (IRC)
- electronic whiteboards
- audio and video conferencing.

Collaborative software (groupware) is software that integrates work by several concurrent users at separate workstations. Users can create and manage information and use different forms of collaboration. Groupware is sometimes divided into three categories depending on the level of collaboration: electronic communication tools (e.g., e-mail), conferencing tools (e.g., whiteboard, videoconferencing, forums), and collaborative management tools (e.g., calendars, workflow systems).

CMC effectively supports constructivism because of the emphasis on access to resources and the extent of collaboration between students promoted through the use of discussion boards. Effective collaboration with peers can be a powerful learning experience and studies have proved its value (Piaget, 1977; Brown and Palinscar, 1989; Doise et al., 1975). However, placing students in a group and assigning a group task does not guarantee that they will have a valuable learning experience (Soller, 2001). It is necessary for teachers to provide effective strategies for students to optimise collaborative learning. Through his Intelligent Collaborative system, Soller (2001) identified five characteristics of effective collaborative learning behaviours:

- participation
- social grounding
- performance analysis
- group processing and application of active learning conversation skills
- promotive interaction

Based on these five characteristics, he listed components of an intelligent assistance module in a collaborative learning system, which include:

- a collaborative learning skill coach
- an instructional planner
- a student or group model
- a learning companion
- a personal learning assistant

Erkens (1997) identified four uses of adaptive systems for collaborative learning:

1) Computer-Based Collaborative Tasks (CBCT)
   Group learning or group activity is the basic method to organise collaborative learning. The system presents a task environment in which students work with a team, and

sometimes the system will support the collaboration via intelligent coaching. SHERLOCK (Katz and Lesgold, 1993) and Envisioning Machines (Roschell and Teasley, 1995) are examples.

2) Cooperative Tools (CT)
The system is a partner that may take over some of the burden of lower-order tasks while students work with higher-order activities. Writing Partner (Salomon, 1993) and CSILE (Scardamalia and Bereiter, 1994) are examples.
3) Intelligent Cooperative Systems (ICS)
The system functions as an intelligent cooperative partner, (e.g. DSA: Erkens, 1997), a co-learner, (e.g. People Power: Dillenbourg and Self, 1992), or a learning companion (e.g. Integration-Kid: Chan and Baskin, 1990).
4) Computer-Supported Collaborative Learning (CSCL)
The system serves as the communication interface such as a chat tool or discussion forum, which allows students to involve collaboration. The systems in this category provide the least adaptability to learners.

Although these systems are still in the early developmental stage, their contribution to the adaptive instructional system field cannot be ignored; they not only facilitate group activities, but also help educators and researchers gain further understanding of group interaction and determine how to support collaborative learning better.

Two main questions are raised:

- How can teachers help students?
- How can teachers be supported by appropriate tools to help students?

(Petrou and Dimitracopoulou, 2003) examined the needs of teachers during synchronous collaboration and found that teachers need:

- a way to easily supervise multiple groups of students that collaborate in a synchronous mode,
- a possible presentation of dialogues linked with the actions in the shared space,
- the history of students actions to appear in the final product, which makes it easier to see who has contributed,
- an appropriate and easier mode to take advantage of the detailed log files of students interactions.

Consequently tools (or tools with partial functionality) such as the following need to be designed and developed:

- supervising tools and facilities,

- an elaborated and linked history of the whole interaction,
- tools that produce an automated analysis of students' interactions, based on the log file related information.

However, all agents involved in the learning process are important, and may need to have specific tools in their disposal: the individual, each specific team, the whole learners' community that is formed, as well as the teacher(s). Nevertheless, it is clear from the above that tools needed to aid these processes require the tracking of the "trails" of learners involved in the activities.

Example of Trails and collaboration within the Colabs project

The "Colabs" project (Colabs, 2002-2004) focuses on finding ways to support children in building and testing models collaboratively across European cultures and beyond. Its objectives are to provide infrastructure for collaborative work; to provide answers for the guiding research questions: "with whom, how and what kinds of knowledge should children learn at a distance?" and "how best can they be supported in this learning?" and to develop learning tools that are transferable into other domains using the Imagine authoring system.

The Colabs portal (which is an example of a CLE) contains vast numbers of activities designed to achieve these objectives. Activities contain course material, tools for creation, convergent and divergent assignments, an uploading area and communication tools. Following advisory maps assigned to projects, each activity in itself could invoke collaborative reactions from participants. Works uploaded to the forum should encourage collaborative work and exchanging ideas. In addition, there are several tools for collaboration: internal messages and discussion forums for asynchronous collaboration, and a chat tool for synchronous collaboration. Further developments aim to provide a summarised view of the achievements of individuals, and a summarised view of value per activity. For these purposes we use and plan further developments of the following trails**:**

Hierarchical maps of projects:

As there are a huge number of learning objects within the portal (tutorials, microworlds, educational games) users are provided advisory maps as navigational trails to follow in project work.

Individual Knowledge Map (IKM)

The Individual Map of each user shows the nodes visited (including the number of hits and time spent there) and logs of paths taken during their visit, which are:

- useful for individuals, because they can reflect on where they have been, what was visited, what was uploaded, what was discussed;
- useful for teachers, because it is easy to supervise and give helpful navigation or ‘what-to-do’ tips for each participant personally;
- useful for future users of the system, because clustering successful paths could provide information on advisable success trails to follow, thus resulting in dynamic advisory trails for project maps.

Activity Map (AM)

The Activity Map is constructed from individual logs. It shows all visited LOs, how many times they have been visited, how the microworlds were evaluated (by votes of users), who visited them, what works were uploaded, and what discussions arose concerning each activity, which are:

- useful for individuals, because they can identify successful LOs;
- useful for teachers, because they can examine pedagogical effects of activities and motivations for collaborative routines;
- useful for designers, because they can examine educational values of activities and can thus improve site by adding more successful LOs and deleting less successful ones, improving the value of portal.

4.2 Collaborative filtering

The explosion in the amount of digital information on the Internet and in other similar distributed network environments means that it becomes more important and difficult to retrieve information adapted to user preferences (Feng-Hsu and Hsiu-Mei, 2004). Personalised recommendation systems are needed to provide recommendations based on users’ requirements and preferences (Mulvenna et al., 2000; Riecken, 2000). In general, there are two types of recommendation systems, the content-based filtering systems and the collaborative filtering systems (Mobasher et al., 2000; Nichols, 1997).

Content-based filtering systems

Content-based filtering techniques are based on content analysis of target items. For example, the technique of term frequency analysis of a text document and its relation to the user’s preferences is a well-known content analysis method. In content-based filtering systems, recommendations are provided for a user based solely on a profile built up by analysing the content of items that the user has rated in the past and/or user’s personal information and preferences. For more on content-based personalisation see TRAILS deliverable 4.1 (Keenoy et al., 2004).

Collaborative filtering systems

In collaborative filtering, items are recommended to a particular user when other similar users also prefer them. The definition of 'similarity' between users depends on the application. For example, it may be defined as users having provided similar ratings for items or users having similar navigation behaviour. A collaborative filtering system collects information about a group of users' activities in the system and calculates the similarity among the users. If some users have similar behaviour, they will be categorised as belonging to the same user group. When a user logs in to the system again, it will compute the group most similar to the user using methods like the k-nearest neighbourhood, and then recommend items preferred by members of the group to the user. A pure collaborative filtering system has several shortcomings and critical issues, including that the coverage of item ratings could be very sparse, hence yielding poor recommendation efficiency; that it is difficult to provide services for users who have unusual tastes, and that there are problems with user clustering and classification for users with changing and/or evolving preferences (Konstan et al., 1997).

Recker et al. (2000) conducted research about how to develop and evaluate a collaborative filtering system called Altered Vista which enables users to share ratings, opinions, and recommendations about resources on the Web. User reviews can be analysed statistically in order to identify clusters of users who have similar opinions, so an additional benefit of the system is that it also allows a user to locate other users that share similar interests for further communication and collaboration. An example of a system using collaborative filtering (or, rather, distributed knowledge) is Syllabnet, available at: http://syllabnet.tmit.bme.hu/portal/servlet/Main?lang=glang2

4.3 A tool for research: Conversational analysis

As we saw in Section 3, analysis of discussion trails can be very useful in the context of CSCL. Analysis of this sort has its roots in the tradition of conversational analysis (CA), which we look at in more detail in this subsection.

4.3.1 Situating CA in traditions of discourse analysis

Discourse analysis considers spoken language and ways of speaking, and beyond this a wide range of elements relating to language use such as who, how, why and when language is used. Language use, communication of beliefs (cognition) and interaction are three main dimensions of discourse. Discourse analyses tend to focus on the topics of:

- *Discourse as Verbal Structure* – Words, gestures, sounds and body language are the observable aspects or expression of discourse. Written discourse is multimodal and an analysis of a written text provides opportunities to examine a range of communications and representations within one text, what Kress et al. (1997) term the *semiotic landscape*.
- *Cognition as Discourse* – Talk and text as expression of language use are also expressions of the knowledge of the speaker or writer. Cognitive models of discourse have been highly influenced by two cognitive theories: symbolic and connectionist theories.
- *Discourse and Society* – Social context is a crucial element of discourse analysis regardless of whether the focus of the analysis is verbal structure or cognition. Discourse is affected by context, and in turn discourse can shape or modify context.
- *Discourse as Action and Interaction: Speech Act Theory and CA* – The central tenet of speech act theory is that speech is action (Austen, 1962). *Speech acts* are its basic unit of analysis, and interaction can take many forms such as agreeing, disagreeing, questioning, answering, developing persona, saving face, attacking, defending, persuading or explaining. These interactions in their social context are the subject of CA.

CA can be construed in a broad sense to mean any study of people talking together in oral communication or language use. However, as a sub-discipline of discourse analysis CA refers to a tradition of analysis founded by Sacks et al. (1974).

4.3.2 Technology and conversation

The seminal CA work by Sacks et al. (1974) articulated three basic facts about conversation: (a) turn-taking occurs, (b) one speaker tends to speak at a time, (c) turns are taken with as little overlap between them as possible (the speakers coordinate their interaction as much as possible to avoid overlap).

Technologies are not neutral (Ellul, 1964) – communication technologies affect the quality and conduct of conversation and interaction. For example, speech is simply not possible in a threaded discussion or bulletin board conversation where typed text is the method by which exchanges occur. The chat window and the distance between client and server machines affect turn-taking and the sequential organisation of the on-line “typed” talk. These characteristics need to be considered as part of the context of the conversation.

“Virtual conversation” is a special case of text-based on-line conversation. Theoretical discussions of the status of virtual conversations have just recently begun to surface in the

CA literature (Hutchby, 2001). Issues such as interpersonal relations, social identities, and frameworks for participation have been researched. Garcia and Jacobs (1999) conducted a comparative analysis of turn-taking in a synchronous chat with the two-party turn-taking structures identified by Sacks et al. (1974), revealing that these virtual conversations (a) have normative characteristics, (b) exhibit unique forms of expression, and (c) contain procedures by which newcomers to the conversational environment are initiated in the use of both a and b. Hutchby (2001, pp. 183–184) found four ways in which virtual conversations on an IRC differ from face-to-face conversations:

1. Participants can take a turn only by entering text in the text line box and pressing the enter key.
2. There is a temporal lag – the “turn” reaches others only when the sent message is accepted and distributed by the remote server.
3. The lag described in 2 results in disjointed sequential relationships between when talk is produced and when it is “enunciated” or displayed on the public talk space.
4. While all of the above is happening, the conversation is conducted in a scrolling window on the shared public space. Depending on the volume of traffic to the server, prior contributions tied to a specific response or turn may scroll off the screen by the time it reaches the public display.

4.3.3 CA: Research questions, data collection and analysis

Sampling can be done using a “specimen” approach drawn from techniques in naturalist observation and biology. A CA study can select any specimen of conversation generated in a naturalistic setting. Hutchby (2001, p. 51) has claimed, “The logic of CA, however, in terms of data selection suggests that *any* specimen is a ‘good’ one, that is, worthy of intense and detailed examination.”

The most important caveat for collecting and producing data for CA is rooted in the concept of “naturally occurring conversation”. Conversation can be recorded in various ways:

1. Audio recordings (analogue or digital)
2. Video recordings (analogue or digital)
3. Text logs from on-line forums (synchronous or asynchronous)
4. Digital screen recordings of on-line interactions (screen playback)

Some kinds of on-line conversations take place within the virtual space of the desktop such as point-to-point videoconferencing. MSN Messenger and Yahoo are two Internet Service Providers who offer on-screen services of this type. Using an inexpensive, small eyeball camera, the people communicating can engage in computer-mediated face-to-face talks.

Using a screen recorder such as HyperCam that captures screen images and stores them as digital movies, a researcher could conduct CA on these types of conversations.

In the preparation of records of conversation for analysis it is important to ascertain the different roles that participants may have in the computer-mediated context – for example, participants may be ordinary "speakers", moderators, sysops (system operators), chanops (channel operators), or have other roles within the formal computer-mediated system.

Several researchers in many contexts have offered suggestions for the task of systematically analysing conversation (Pomerantz and Fehr, 1997; ten Have, 1999). The most concrete suggestions for the steps in the analysis of conversation are:

1. Select a sequence – either a purposive or an arbitrary selected segment of a transcript;
2. Characterise the sequence;
3. Consider the rights, obligations and expectations constituted in the talk.

Even though an on-line chat or forum may be "public" (the chat logs are archived and available for group inspection), it is important for the researcher to maintain an ethical posture toward informing participants that their work will be the subject of analysis either by a "participant-observer" or by an external researcher.

4.3.4 Hardware, network tools and software for CA

Word processors are clearly a key tool for CA due to their text processing capabilities. Features such as line numbering, search and replace, and options for formatting and displaying text are invaluable for processing transcriptions used in CA.

Qualitative text analysis programs such as ATLASti[7] and NVIVO[8] provide tools for coding and restructuring the data along categorical dimensions defined by the researcher. Using this kind of software, which typically utilises multiple windows to categorise, link, and sort data, it is possible to develop graphical "tree" displays of related text data chunks and to group data in "families" to support complex analyses.

Graphical cluster displays of "neural net" text data – CATPAC[9] is a neural network program designed to read and understand text. It works by learning the interrelationships

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[7] http://www.atlasti.com/

[8] http://www.qsrinternational.com/

[9] http://www.thegalileocompany.com/

among words and phrases in the text, and can identify the underlying concepts in a text after only a single reading.

Transcription and analysis of video data can be facilitated using Transana[10] software, which provides a way to view video, create a transcript, and link places in the transcript to frames in the video. Analytically interesting portions of videos can be identified and organised, and keywords can be attached to those video clips. It also features database and file manipulation tools to facilitate the organisation and storage of large collections of digitised video.

Computer tracking logs provided by the internal archiving features of many text-based on-line chat, bulletin board, newsgroup, or threaded discussion applications are essentially time-and date-stamped text logs of the typed-in talk, often with additional usage statistics such as numbers of users and the amount of time spent in the forum. There are also tracking tools that can be operated on the network servers supporting these on-line forums, such as the AXS[11] tracking utility (that provides graphical and real-time log data analysis) and StatCounteX[12]. Such tools may have as yet untapped potential for documenting online talk-in-interaction; specifically, one can envision the need to document a student's "hits" in a Web-based instructional unit that might be cross-referenced with on-line synchronous mentoring of a student who was exploring the information on that site. Although these kinds of on-line talk-in-interaction are not commonly used or researched, the potential for this type of conversation clearly exists. In fact, the entire area of on-line facilitation and so-called e-moderating has only recently received serious attention (Collison et al., 2000).

Screen recorders of on-screen interactions such as Hypercam[13] can be useful for CA.

Other tools for visualising conversation are Chat Circles, a graphical interface for synchronous conversation, and Loom, a visualisation of threaded discussions. These have been developed for the purposes of investigating the underlying social patterns in these highly visual, graphically represented on-line conversation forums.

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[10] http://www.transana.org

[11] http://www.xav.com/scripts/axs/

[12] http://www.2enetworx.com/dev/projects/statcountex.asp

[13] http://www.hyperionics.com

5 Collaborative support in the “academic” state-of-the-art

We have now looked at the theoretical underpinnings of systems supporting collaborative learning and also have an idea of issues involved in their design and some techniques that can be used within such environments. We now report on some of the existing research systems and state-of-the-art collaborative learning systems currently available that have put some or all of these ideas into practice. After selecting the most pertinent systems to study we have defined a common framework to characterise the different proposed approaches from a “trail” point of view. From this framework we propose to categorise the different models or tools found in the field of e-learning systems. The survey we give is intended to be representative of the field today, not exhaustive. Several state-of-the-art studies can be found in the context of recent projects concerning CSCL, notably:

- A deliverable of the ITCOLE project (Innovative Technology for Collaborative Learning and Knowledge Building) (ITCOLE, 2000). This work contains two sections named "CSCL environments and approaches" and "Adaptive educational systems and approaches", dedicated to a review of existing models and tools;
- A deliverable (D12) of the Alfanet project (Active Learning for Adaptative Learning) (Alfanet, 2002). This work contains two sections named "CSCL environments and approaches" and "Adaptive educational systems and approaches", dedicated to a review of existing models and tools;
- A research paper (Jermann et al, 2001) "From Mirroring to Guiding: A Review of State of the Art Technology for Supporting Collaborative Learning", more specifically dedicated to reviewing systems that support the management of collaborative interaction. This paper proposes a classification framework built on a model of coaching, which appears particularly relevant to our "trail" point of view. Details of Jermann et al.’s classification framework are given in 5.1.

After presentation of this taxonomy, we propose a framework derived from Koper's works on educational modelling languages to categorise the different systems, linked to the concepts of "planned trail" and "effected trail". The section concludes with a look at some of the main ongoing research issues in collaborative learning.

5.1 Jermann’s taxonomy of collaborative systems

Jermann, Soller and Muehlenbrock (Jermann et al., 2001) review systems that support the management of collaborative interaction, and propose a classification framework built on a simple model of coaching.

They define a lifecycle composed of 4 steps : data collection, structuring indicators, diagnostics and remediation.

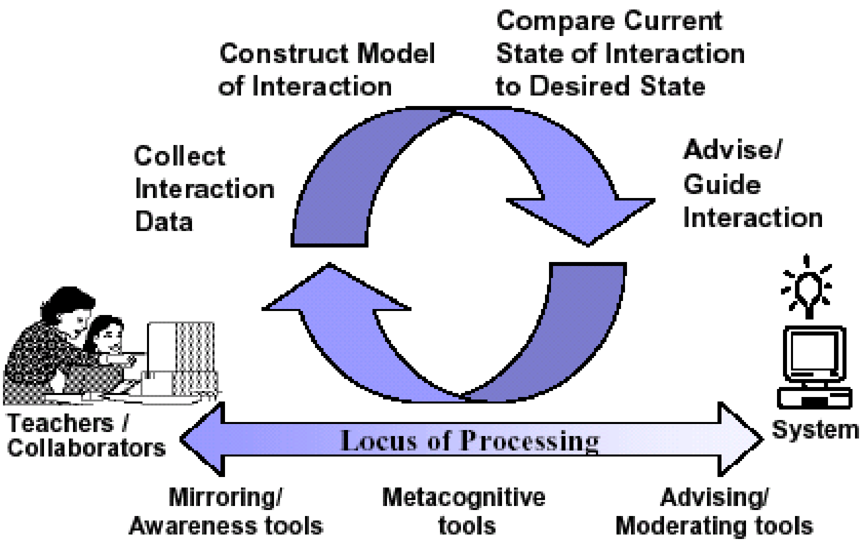

Figure 3: Managing collaborative interaction

Among systems that support collaboration, two approaches can be adopted:

1. The ***prescriptive approach*** structures collaborative learning situations by requiring the students to use a set of structured software tools, structuring the group itself or structuring the task. These factors may encourage group members to engage in certain types of interaction such as argumentation or peer tutoring via external means.
2. The ***regulative approach*** involves structuring the collaboration itself through coaching or self-regulation. As the collaboration progresses, the state of interaction is evaluated with respect to a desired state, and remedial actions may be proposed to reduce discrepancies between these states.

Prescriptive and regulative are not exclusive approaches, as structuring interaction might take place during interaction as a remedial action.

Jermann's framework distinguishes between three types of supportive collaborative learning systems, which are discussed in detail in the following subsections:

- Mirroring Systems, which display basic actions to collaborators;
- Metacognitive Tools Systems, which represent the state of interaction using a set of high level indicators derived from raw data;
- Coaching or advising systems, which guide the collaborators by recommending actions students might take to improve their interaction.

5.1.1 Mirroring systems

Systems that reflect actions, termed mirroring systems, collect raw data in log files and display it to the collaborators. The most basic level of support a system might offer involves making the students or teachers aware of other participants' actions. Actions taken on shared resources, or those that take place in private areas of a workspace may not be directly visible to the collaborators, yet they may significantly influence the collaboration. Raising awareness about such actions may help students maintain a representation of their team-mates' activities.

Plaisant et al. (1999) describe a system in which students learn the basics of vacuum pump technology through a simulation. As the learner manipulates the controls of the simulation, a history of actions is displayed graphically beneath the target variable (e.g. pressure). It consists of stripes and boxes that represent the user's actions as well as the system's messages. The data displayed to the student does not undergo any processing or summarising, but directly reflects the actions taken on the interface. These graphical records of actions can then be sent to a tutor or a peer, or replayed by the learner to examine his own performance.

Some systems in this category represent actions along a timeline.

5.1.2 High-level monitoring systems

Systems that monitor the state of interaction fall into two main categories: those that aggregate the interaction data into a set of high-level indicators, and display them to the participants, and those that internally compare the current state of interaction to a model of ideal interaction, but do not reveal this information to the users. In the former case, the learners are expected to manage the interaction themselves, having been given the appropriate information to do so. In the latter case, this information is either intended to be used later by a coaching agent, or analysed by researchers in an effort to understand and explain the interaction.

Many groupware systems provide users with information such as where other users are located (if the system uses a room-based paradigm), or what objects other users are viewing or manipulating (NCSA Habanero, CuseeMe, Collaborative Virtual Workspace, Microsoft NetMeeting)

The benefits of coaching student interaction (via human or computer) are clear, given a correct diagnosis and appropriate remedial actions. Students who view and analyse indicator values may learn to understand and improve their own interaction. However, they might lack the understanding to interpret the visualisations correctly, leading them to take unnecessary actions. Without the time and understanding to develop their own models of interaction, students may naturally rely on implicit social norms (status, equality) to manage the interaction. Collaborative learners, guided by indicator displays, may need to follow a more introspective process to develop an understanding of their interaction than when they are guided by an advisor.

Visualisation and manipulation of high-level indicators

The first group of systems model the state of interaction via a set of indicators that are displayed to the users. Such tools might have a positive impact on a group's metacognitive activities by aiding in the construction and maintenance of a shared mental model of the interaction. A mental model may encourage students to discuss and regulate their interaction explicitly, leading to a better coordination of the joint effort to reach a solution. Taking these ideas one step further, we might imagine a system whose model of desired interaction is displayed to the students next to the actual state of interaction. The model might also change during the learning process, causing the target values of the indicators to be dynamically updated, encouraging the learners to improve in different ways.

Visualising social networks

In situations where more than two people interact, social networks may be used to represent the exchange patterns among participants in a discussion (Nurmela et al., 1999). A social network typically consists of a network of nodes in which each node represents a participant. The thickness of an edge connecting any two nodes represents the amount of discussion between two participants. Simoff (1999) proposes an interesting way to merge the graphical representation of participation rates, and the potential for learning. His system visualises discussion threads with nested boxes. The thickness of the boxes' edges represents the number of messages produced in response to the opening message for a particular thread. In an educational environment, thicker boxes might mean deeper conversations, hence deeper understanding.

Visualising knowledge maps

Some indicators are implicitly contained in the tools used by the students.

In Sharlock II (Ogata et al., 2000), a special tool called a Knowledge Awareness Map graphically shows who is discussing or manipulating the knowledge pieces users have posted. In this case, the distance between users and knowledge elements on the map indicates the degree to which users have similar knowledge.

Visualising qualitative data about interaction and dialog

The systems discussed so far refrain from interpreting the content of the interaction and instead focus on quantitative aspects of the interaction. Analysis of participation rates involves counting words or messages, whereas indicators such as acknowledgement rate and delay (how often users respond to incoming messages, and how long this takes) or role distribution (what kind of actions are taken by whom) require more sophisticated computation (e.g. advanced modelling or natural language processing techniques). Studying more complex variables often involves analysing the semantic aspects of interaction and the patterns of student actions. A structured interface may facilitate the interpretation of actions by the system. For example, users may be required to select a dialog act (e.g. propose, encourage, question) when they send messages to each other.

MArCo (Tedesco and Self, 2000) is a dialog-oriented system for the detection of meta-cognitive conflicts. The system adopts a dialog game approach with a limited set of possible dialog moves. User utterances must be formulated in a formal language that enables the conversation to be mapped onto a belief-based model (BDI). The analysis mechanism detects disagreements and conflicts between users' beliefs and intentions.

Conversational acts may be considered in isolation, or in the temporal context of other acts.

Muehlenbrock and Hoppe (1999) were one of the first to propose actions in shared workspaces as a basis for a qualitative analysis. Unlike dialog tags, actions on external representations are not only interrelated on a temporal dimension, but also on a structural dimension, i.e. concerning their context of application. This approach has been termed action-based collaboration analysis (Muehlenbrock, 2000) and is implemented as a plug-in component in the generic framework system CARDBOARD/CARDDALIS, which enables collaboration by means of shared workspaces with structured external representations (visual languages) and provides intelligent support. Action-based collaboration analysis derives higher-level descriptions of group activities, including conflicts and coordination, based on a plan recognition approach.

Coaching agents

One reason for not displaying a visualisation of the model of interaction to the students or the teacher is that the evaluation of complex variables contains a margin of error; hence it may be more appropriate to abstract the relevant aspects of the model before presenting them to the users.

HabiPro (Vizcaino et al., 2000) is a collaborative programming environment that both displays the students' participation statistics, and models more complex interaction variables. The system includes a group model and an interaction model, which includes a set of "patterns" describing possible characteristics of group interaction (e.g. the group prefers to look at the solution without seeing an explanation). During the collaborative activity, the group model compares the current state of interaction to these patterns and proposes actions (such as withholding solutions until the students have tried the problem).

EPSILON (Soller and Lesgold, 2000) monitors group members' communication patterns and problem solving actions in order to identify situations in which students effectively share new knowledge with their peers while solving object-oriented design problems. In the first phase of the collaboration management cycle (Figure 3), the system logs data describing the students' speech acts (e.g. Request Opinion, Suggest, Apologise) and actions (e.g. Student 3 created a new class). In the second phase, the system collects examples of effective and ineffective knowledge sharing, and constructs two Hidden Markov Models which describe the students' interaction in these two cases. A knowledge sharing example is considered effective if one or more students learn the newly shared knowledge (as shown by a difference in pre-post test performance), and ineffective otherwise. In the third phase, the system dynamically assesses a group's interaction in the context of the constructed models, and determines if the students need mediation.

5.1.3 Advising systems

This section describes systems that analyse the state of collaboration using a model of interaction, and offer advice intended to increase the effectiveness of the learning process. The coach in an advising system plays a role similar to that of a teacher in a collaborative learning classroom. This actor (be it a computer coach or human) is responsible for guiding the students toward effective collaboration and learning. Since effective collaborative learning includes both learning to effectively collaborate and collaborating effectively to learn, the facilitator must be able to address social or collaboration issues as well as task-oriented issues. Collaboration issues include the distribution of roles among students (e.g. critic, mediator, idea-generator), equality of participation, and reaching a common understanding. Task-oriented issues involve the understanding and application of key domain concepts. The systems described here are distinguished by the nature of the information in their models, and whether they provide advice on strictly collaboration issues or both social and task-oriented issues. We begin by taking a look at systems that focus on the social aspects of collaborative learning.

A classroom teacher might mediate social interaction by observing and analysing the group's conversation, and noting, for example, the levels of participation among group members, or the quality of the conversation. A CSCL system that can advise on the social aspects of interaction therefore requires some ability to understand the dialog between group members.

Barros and Verdejo’s (2000) asynchronous newsgroup-style system, DEGREE, accomplishes this by requiring users to select the type of contribution (e.g. proposal, question, or comment) from a list each time they add to the discussion. This data satisfies the first phase of the collaboration management cycle. The system’s model of interaction (phase 2 of the collaboration management cycle) is constructed using high-level attributes such as cooperation and creativity (derived from the contribution types mentioned above), as well as low-level attributes such as the mean number of contributions. In the third phase of the collaboration management cycle, the system rates the collaboration between pairs of students along four dimensions: initiative, creativity, elaboration, and conformity. These attributes, along with others such as the length of contributions, factor into a fuzzy inference procedure that rates students’ collaboration on a scale from “awful” to “very good”. The advisor in DEGREE elaborates on the attribute values, and offers students tips on improving their interaction. A limitation of the DEGREE approach might be its dependence on users’ ability to choose the correct contribution type (proposal, comment, etc.). An alternative way of obtaining this information is to have users select sentence openers, such as “Do you know”, or “I agree because” to begin their contributions. Associating sentence openers with conversational acts such as Request Information, Rephrase, or Agree, and requiring students to use a given set of phrases, may enable a system to understand the basic flow of dialog without having to rely on Natural Language parsers. Most sentence opener approaches make use of a structured interface, comprised of organised sets of phrases. Students typically select a sentence opener from the interface to begin each contribution.

McManus and Aiken (1995) take this approach in their Group Leader system. Group Leader builds upon the concept that a conversation can be understood as a series of conversational acts (e.g. Request, Mediate) that correspond to users’ intentions (Flores et al., 1988). Like Flores et al.’s Coordinator system, Group Leader uses state transition matrices to define what conversation acts should appropriately follow other acts, however unlike the Coordinator, users are not restricted to using certain acts based on the system’s beliefs. Group Leader compares sequences of students’ conversation acts to those recommended in four finite state machines developed specifically to monitor discussions about comments, requests, promises, and debates. The system analyses the conversation act sequences, and provides feedback on the students’ trust, leadership, creative controversy, and communication skills.

The success of McManus and Aiken’s (1995) Group Leader began a proliferation of systems that take a finite state machine approach to modelling and advising collaborative learners.

One year later, Inaba and Okamoto (1996) introduced iDCLE, a system that provides advice to students learning to collaboratively prove geometry theorems. This system infers the state of interaction by comparing the sequences of conversation acts to one of four possible finite state machines. Advice is generated through consideration of the dialog state and the roles of each group member.

The next three collaborative learning systems interact with students via a set of specialised computer agents that address both social and task-oriented aspects of group learning.

GRACILE (Ayala and Yano, 1998) is an agent-based system designed to help students learn Japanese. The system maintains user models for each of the students, and forms beliefs about potential group learning opportunities. Group learning opportunities are defined as those that promote the creation of zones of proximal development (Vygotsky, 1978), enabling a student to extend her potential development level. GRACILE's agents assess the progress of individual learners, propose new learning tasks based on the learning needs of the group, and cooperate to maximise the number of situations in which students may effectively learn from one another.

The models of interaction employed by LeCS (Rosatelli et al., 2000), and COLER (Constantino-González and Suthers, 2000) also integrate task and social aspects of interaction. LeCS is similar to GRACILE in that a set of computer agents guide students through the analysis of case studies. The agents monitor students' levels of participation, and track students' progression through the task procedure, while addressing students misunderstandings and ensuring group coordination.

COLER uses decision trees to coach students collaboratively learning Entity-Relationship modelling, a formalism for conceptual database design. For example, the coach might observe a student adding a node to the group's shared diagram, and might notice that the other group members have not offered their opinions. The coach might then recommend that the student taking action invite the other students to participate. The system also compares students' private workspaces to the group's shared workspace, and recommends discussion items based on the differences it finds.

5.2 Proposed framework for categorisation

We propose to adapt the Jermann taxonomy based on our previous work on learning scenarios (Pernin and Lejeune, 2004, Lejeune and Pernin, 2004).

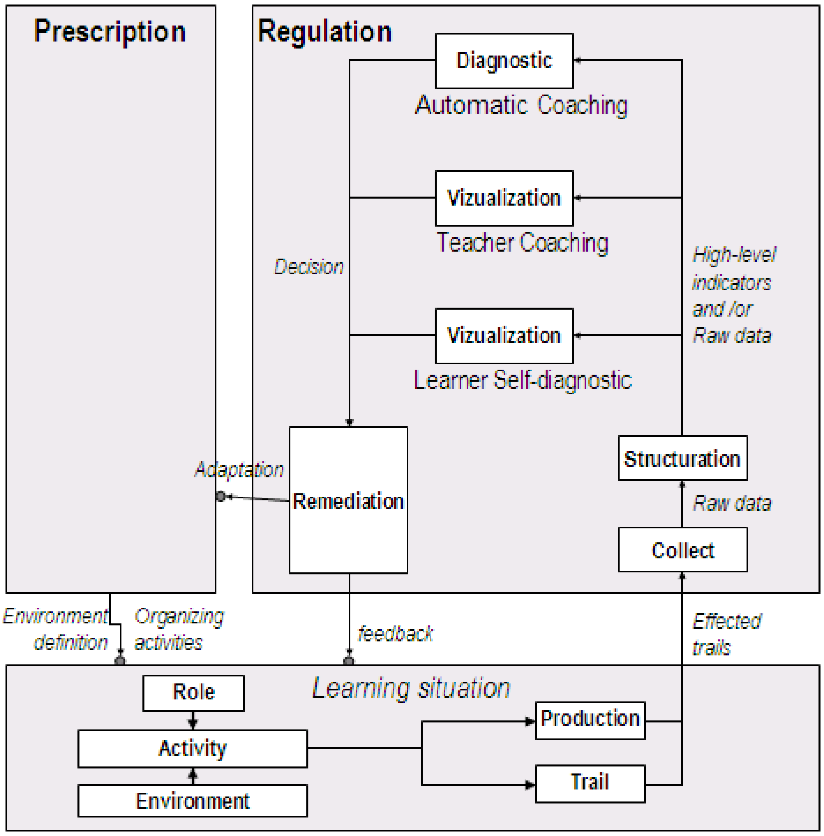

Figure 4: The different facets of a learning scenario

(adapted from Pernin and Lejeune, 2004)

This model, derived from models promoted by Koper in IMS-LD (Koper, 2001, 2004) separates two facets of a learning situation : the prescriptive facet and the regulative facet. The prescriptive facet precisely describes the activities to be performed by the actors and the environment (resources, tools, learning objects) in which the situation takes place. One part of this description concerns the planned trails proposed to the actors of the collaborative learning situation.

Each individual or collaborative activity is able to produce a result – either an explicit production (such as an exercise or answer to a question) or a simple action that constitutes an index of the activity and element of a trail (such as a click on an element or navigation). The regulative facet deals with the processing of the "effected trails" in order to regulate the learning situation. This regulation is composed of four steps:

1. Collecting effected trails that emerge from the collaborative activities and that can be considered as raw data;
2. Building more sophisticated indicators by structuring the initially collected raw data;
3. Diagnostics using raw data and high level indicators. Three approaches to this are:
    - Learner or group self regulation
    - Teacher coaching
    - Automatic coaching

In the two former approaches, the diagnostics are performed by a physical role (learner, group or teacher) and require the visualisation of raw or high level indicators. This visualisation must be adapted to the specific type of user in order to allow him to take relevant decisions. In the third approach, the diagnostic is automatically performed by a computer from a set of techniques linked to artificial intelligence.

4. Regulation of the situation. This regulation must provide simple feedback to users or adapt the conditions of the learning situation.

Using this adapted framework, we categorise e-learning systems or models including personalisation and collaboration features in the table below. This categorisation takes following criteria into account:

- Type of learning: (I)ndividual or (C)ollaborative
- Type of regulation: Learner/Group Self Diagnostic, Teacher coaching, Automatic Coaching
- Type of collected effected trails
- Type of Structured data or high-level Indicators
- Type of remediation (Adaptation, Feedback)

The following table shows the categorisation of some representative systems presented in this section.

5.3 Categorisation of several representative models and tools

Name of system or model	(I)ndividual or (C)ollaborative learning	Type of regulation			Type of collected effected trails	Type of Structured data or high-level Indicators	Type of remediation (Adaptation, Feedback)	Commentaries
		Learner/Group Self Diagnostic	Teacher coaching	Automatic Coaching				
AFL			x		Collaboration data: - interaction in the forum - Survey of versioning - Ratings by students	Group activity indicators : - students performances in collaborative tasks (participation collaboration, usefulness, reputation, etc.)	Adaptation of learning environment by tutors	Based on Logical Framework Activity typical activity for workgroups
Synergeia	I,C	G			Co-construction of conceptual maps	Conceptual maps	Adaptation by teachers of learning environment	Co-construction of conceptual maps
Habipro	C	G			Type of asked help Interaction in chat Detected mistakes	Group motivation Degree of participation	Adaptation of learning by proposing adapted exercises	Exercising environment to develop programmer's skills
GRACILE	I			x	Message production of short phrases	Languages patterns	Automatic assistance with talking heads	Second language learning
MAPTOOL			x		Log events	Presence awareness Collaboration awareness Progress of construction of knowledge artefacts		Collaborative drawing of concept maps

5.4 Ongoing research issues in collaborative learning

Research in distributed learning generally focuses on:

1. **learning communities** comprised of people with varying backgrounds and expertise;
2. **technology** supporting communication and productive activity within a community;
3. **engagement** in authentic activity.

The central focus for research in CSCL is on ***instruction as enacted practice*.**

Open research problems include:

1) Exploring the use of mobile devices for providing distance education;
2) Vicarious learning and informal discussion environments;
3) The possible tension between different structured learning activities;
4) New forms of assessment made possible by online interaction, especially among groups of learners (for example, novel assessment methods might be developed that reflect team working ability and knowledge management skills);
5) Research on different learners
   - how best to use CMC within multicultural and unicultural groups
   - gender differences
   - collaborative learning between different professional groups
   - the extent to which different types of learner need to belong to a community in order to maximise the chances of success in both the development of the learning community and the meeting of individuals' learning needs;
6) Investigation of functionalities that do not exist in face-to-face interactions, for instance the possibility for learners to analyse their own interactions, or to see a display of their group dynamics.

6 Collaborative trails in mobile learning

Deliverable D22.2.1 (Schoonenboom et al., 2004) included a selective review of research on the use of mobile learning in museums and related contexts (mainly concerning informal learning) and also for field work in learning Science with the aim of informing issues concerning the use of mobile devices and personalised learning trails. It was argued that "*navigational* learning" (Peterson and Levene, 2003), one of the areas that personalised trails should be able to support, often involves what has been termed a 'free-choice learning' activity (Falk and Dierking, cited by Proctor and Tellis, 2003, and Waycott, 2004). Free-choice learning is defined as 'the type of learning guided by a person's needs and interests'.

As stated in D22.4.1 (Keenoy et al., 2004), there has been an explosion of interest and projects in the area of mobile learning and it would not be possible or productive to review this vast literature – see, for example, the links and projects at http://cc.oulu.fi/~jlaru/mlearning/. This section considers collaborative aspects of mobile learning and explores some of the issues around creating and tracking collaborative trails in such an environment.

6.1 Collaborative learning and mobile learning

Deliverable D22.2.1 (Schoonenboom et al., 2004) includes discussion of Sharples' approach to mobile learning and his model of personal learning. In line with many contemporary researchers in educational technology this model is developed from the premise that learning is social and so the model is concerned with collaborative learning. Learning is also viewed as a social activity in one of the key more general contemporary theoretical approaches – the sociocultural approach.

Indeed, much of the recent literature that falls under the rubric of "mobile learning" research has focused on the use of PDAs as collaborative learning tools in school settings, both inside and outside the classroom (e.g., Curtis et al., 2002 and Hennessy, 2000). For instance, Hennessy (2000) described a study in which secondary school students were given handheld computers to use on a collaborative project in which small groups of students worked together to record weather pattern data and prepare graphs of their results. Because students each had access to their own learning materials on the handheld computer, they maintained a sense of personal ownership over the data and project. Personal ownership, or learner control, is considered an important aspect of effective learning (Sharples, 2003). Students collected data from a variety of sources, using the handheld in many different locations. It is unsurprising, then, that they rated “flexibility and use outside classroom” as the greatest benefit of using the palmtop computer.
Similarly, Curtis and colleagues described a school class that used iPAQ handheld computers that could be used to access to the school's wireless network. In this setting, the PDAs were used as “inquiry-based scientific research tools” for assignments that each lasted several weeks. Using the wireless network, students could “go online and find information from wherever they [were] in the school area – whether [they were] outside collecting science data or in the cafeteria discussing questions over lunch” (Curtis et al., 2002, p.28).

A case study example of researching the use of mobile devices for learning and information use

In one recent project on the use of mobile devices, Waycott (2004) has taken an activity theory approach to researching the use of PDAs for supporting learners (by having some of the course work on them), and mobile workers. The activity theory approach allows her to identify and analyse contradictions and disruptions from using these devices. It also highlights how the users' activities change when they adopt new technologies and in turn how the use of the technology is changed and adapted to the activities.

Waycott develops a theoretical account, using Activity Theory, of the process of technology appropriation (how learners use and adapt technologies to their purposes) and the shaping effect of technology on individuals and their social environment. She uses Engeström's (1987) activity model to describe the process of technology adoption and also develops a model of the *Tool Integration Process*. Together these two models provide the framework for analysing four case studies to address two central research questions: How are PDAs appropriated as learning and workplace tools? How do PDAs mediate learning and workplace activities?

The data that Waycott has collected in different contexts provides a clear illustration of how people vary in the way they respond to, and use, new technologies, and how such technologies consequently come to be integrated into users' activity systems. Participants varied in their expectations and evaluations of the PDA, based on differing past experiences, personal preferences, and existing work and study practices.

Some of the participants in Waycott's studies who were using the PDAs to access course materials for a university distance learning course found them an invaluable tool that allowed them to make use of small amounts of spare time. For these part time learners this was really important. Even so, use of the PDAs meant rethinking the way that they used and engaged with the texts. For example, students often used highlighting on paper texts and also relied on the navigational cues found in traditional books. These features were absent on the PDAs and students found this frustrating. But for some the advantages were such that they were prepared to cope with eyestrain and headaches caused by working with the small screens. In a different case study, participants found that the PDAs they were provided with could be easily used to enable them to carry out their existing activities. For instance, one participant appreciated being able to take notes from meetings on the PDA and being able to transfer these to the desktop to form the basis of the document to be produced. Others, for example those who touch typed, found they could make good use of the keyboard accompanying the PDA, but could not adapt to using the stylus or the "handwriting" as their touch-typing was a fast efficient way of producing text. Others found the limitations of the small screen and awkward input methods too much to cope with. Participants varied greatly in the amount of motivation and time they were able to bring to the task of learning to use the PDAs.

It is clear from Waycott's study that viewing mobile devices as technologies or tools that can be adopted, or not, to support learning, is too simplistic. Commercially available mobile devices have not been developed with learners in mind and the very functions that make them attractive (small size, portability) also constrain them considerably – and for some learners these constraints will override any advantages. But using the PDAs also changes the activities that are being carried out – as in the way that learners engage and work with texts that they are studying. As yet, designers of such devices do not appear to be taking such considerations into account.

For example, in D22.2.1 the use of handhelds in London's Tate Modern was described, including the e-mail facility that was provided. Waycott (2004, op. cit.) carried out a small study in the Tate Modern and reports that this function which allows visitors to communicate with each other was constrained by there being a limited choice of prepared text as it offered standard options for users to text each other with messages such as 'I am tired/cold/hungry'. Waycott reports that this option could certainly have benefited from asking users what they would like to send: the development of the facility does not seem to have taken into account the ways users would like to use email in this context and how it fits with the activities that they normally engage in these contexts.

In this context there are several constraints that would need to be overcome in some way for the device to be successfully integrated into the user's activities. The constraints included a novel interface, an awkward way of carrying a new tool – and that it used up hands needed for other activities – writing notes, for instance. Furthermore, one of the benefits of mobile devices is their personal nature, which gives users a strong sense of ownership. It also means that it is usually worthwhile investing some time in learning about the device. In this context, when the device is only used for 50 minutes or so, some of these 'personal' benefits are lost and users will not invest time in a steep learning curve in order to understand the interface: how to use the interface must become quickly apparent.

Issues arising from field studies in using mobile devices: implications for collaborative work

The issues identified in D22.2.1 included technical and interface issues. Some of these of course disappear with time – processors become more powerful, for example. However, others such as battery life, charging and the weight of the devices remain an issue, as does the interface as noted above. The field work in museums that we have discussed here has not focused specifically on the collaborative use of mobiles, although the ‘Rememberer’ (developed at the Exploratorium) “is intended to aid personal recall, stimulate discussions and other forms of social interaction and support users’ research or classroom work”.

These devices (discussed in D22.2.1) allowed Exploratorium visitors to make a visit record in the form of web pages and a physical artefact that is a reminder and pointer to the visit record. The final visit record contains the list of exhibit names in the order visited; pointers to the content (usually web addressed) and many exhibits also have cameras and photographs were taken when the exhibit was visited, which could be accessed later. While this device is a good example of one of the ways discussed by Peterson and Levene (op. cit.) in which navigational learning can be supported, it does not specifically involve or require collaborative or social activity. Its developers noted that visiting museums and art galleries are social activities; that visitors discuss exhibits – especially ambiguous or ‘challenging’ exhibits. Whilst these devices are designed to allow for this; they do not explicitly build in social or collaborative learning; unlike, for example, the research carried out by Curtis et al. and Hennessy on collaborative work in classrooms using mobiles (described earlier).

The other context that was discussed in D22.2.1 was that of the use of mobiles for fieldwork. This included some *requirements* of mobile computer usage for fieldwork as outlined by Pascoe and colleagues (Pascoe et al., 2000); some of which it is argued have a more general applicability:

1. **Dynamic user configuration:** put simply, the user is mobile and could be using the device whilst lying down, standing or walking: the device must allow for this.
2. **Limited attention capacity:** the user must be able to use the device without giving it all his or her attention.
3. **Context dependency:** location is particularly important and will need to be recorded: in many cases this might require plotting observations on to a map. (This is already widely used in many contexts)

6.2 Navigating, location, context awareness

The examples of the use of handhelds in museums and in fieldwork described here and in more detail in D22.2.1 rely on context awareness, i.e., systems being aware of their context of use. One of the largest projects currently considering this issue is the MOBILearn project[14], and the University of Birmingham team is leading work on this aspect. Byrne et al.

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[14] http://www.mobilearn.org/

(2004) outline the advantages and disadvantages of various methods to determine the location of learners. They categorised approaches into:

- Absolute spatial co-ordinates (e.g. x,y,z) vs. proximity (how near learner is to an object of interest) and
- Interactive (learner initiates detection of location) vs. transparent (location detection is always on).

Difficulties in making use of such location information include how to distinguish *interest* in an object from *proximity* to an object. Work is ongoing to address these difficulties and on integrating the location information into a rounded context awareness system.

7 Collaborative support in the “commercial” state-of-the-art

We have so far looked at the state-of-the-art of mainly experimental systems. We now briefly report on some of the best-rated commercially available (and so more widely used) systems and products. We have selected these based on information from the Brandon-Hall web site, the e-learning stock market[15], the press, and informal exchanges between professionals of the Human Resource and Training areas.

Centra[16] has been one of the first providers to bet on the collaborative aspect of learning: "Centra's online solutions allow addressing the needs of the individual to capture, share and manage information and skills in a variety of formats...”. Centra's complete solution for collaborative learning includes Virtual Classes, Web Seminars, Online Meetings, Content Creation, Related Professional Services and Integration Capabilities.

The functionalities relating (directly or indirectly) to the concept of trails are:

- The recording of live sessions – useful for those who wish to review materials covered in the live session;
- The development of personalised learning tracks: customised training materials and activities based on skill level – useful for tracking learner's progress through online tests and quizzes;
- Delivery of blended learning programmes, providing access to both live and recorded sessions, allowing users to import self-paced knowledge objects into the live sessions;
- Collection of feedback: online evaluations provide insights and recommendations for improvement;

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[15] http://www.brandonhall.com/public/ticker/

[16] http://www.centra.com

- Tracking skills development: measurement of individual and team performance with testing and assessment tools;
- Generation of post-event reports: issue customised attendance, learning activity, knowledge reports to fuel future development criteria.

We observe that although there are functionalities allowing progress to be tracked, there is no ability to revisit personal trails for reflective purposes. An example of possible improvement in this sense could be to allow the user to revisit the feedback collected during the live sessions. Another possibility would be to take advantage of post-event reports, not only to fuel future development criteria, but also to feed back information to learners.

As **Saba**[17] states on its welcome page, it continues to be the system to which other LMS's are benchmarked (Brandon-Hall 2004). Saba offers a variety of tools for collaborative sessions:

- The "Saba Collaboration^{TM}" product offers the following features: communities of practice, automatic member assignment, document and question-and-answer sharing, chat and threaded discussion, expert location. This product does not seem to offer tracking or other facilities supporting trails.
- The "Saba Live!^{TM}" product enables real-time, web-based interactive learning events to be conducted. It allows the leveraging of previous learning events by recording and viewing archived sessions. Features include: synchronous learning events including polling, question-and-answer sessions, chat, application sharing and viewing, panel presentations with multiple instructors, and replay functionality to capture everything in the learning event – including application sharing, demos and annotations.

While Centra does not seem to offer tracking features or facilities related to trail support, the last feature of the Saba Live induces us to think that it could be improved for use in “trail revisiting”.

So it seems that some collaborative tools are now being included in commercial systems, but there is much more yet to come to market in terms of both tools and pedagogical advice on how they can best be used.

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[17] http://www.saba.com

8 Looking to the future: Scenarios for collaborative trails

8.1 Recording collaborative trails – Amy Mermaid discusses the Odyssey with her students

The scenario

Amy Mermaid is preparing her lesson on Homer's magnificent epic the Odyssey. This week, the discussion will be about the scene in which Odysseus blinds the one-eyed Cyclops Polyphemos. The assignment that is given to the students is the same every week. They have to prepare the meeting by reading the text very carefully, and by discussing for each paragraph the use of metaphor, the role of the scene within the whole epic, the relation to other scenes in the Odyssey, signs of orality, and the history of the text as it is delivered to us.

Amy uploads the text to the digital learning environment. The text is automatically cut into pieces of one poem line each. When the students click on the text title, the text appears in the left half of their screen as one integrated text. Some of the lines are marked by a small triangle, and if students click on the triangle, they see the trail of comments that other students made regarding that line. The comments just show the comment itself and the author; they are listed in threads, and in the order in which they were made. If students want to, they can expand all comments at once.

Furthermore, all poem lines are preceded by a number. If a student clicks on a line, the text of that line appears in the right upper half of the screen. At the same time, in the lower right part of the screen, a box appears, in which the student can type his or her comment. Below the text box, a simple Submit button is shown.

Discussion

At first sight, this scenario does not look too futuristic. In fact, the discussion environment that is described in this scenario has been developed and implemented a few years ago (see Schoonenboom 2002). At closer look, however, reveals that it has some features that today's learning environment lack, and that strongly facilitate both discussing texts and reviewing discussion trails. These features include:

- No unnecessary headers of messages. Standard discussion forums first show a set of headers, and only by clicking on a header, a reader can access the corresponding message. This poses an extra burden on the user, in that an extra mouse click is required to access the information they want to see. What is much worse, a burden is posed by the headers themselves, usually simply ‘ RE: subject’. The headers provide hardly any clues to the reader as to the content of the message

- More generally, unnecessary information is avoided. For example, with the comments, only the comment itself is displayed plus the author, but no information is given on the date and time the comment was posted, or the email address of the author. The chronology of the comments is indicated by their order, and that is sufficient with this type of use.
- The clickable numbers before each poem line function as anchor points for discussion. Each anchor point can be used as a starting point for discussion. This means that users do not themselves have to select a point where they wish to start a discussion. In this design, the number of anchor points is equal to the number of poem lines, which means that a substantial number of points is created from which by a simple click a discussion can be started.
- The design allows for different representations of the text. Users can either view the text as a whole, without the comments, or view the text with comments, or parts of the text with, parts of the text without comments. Most learning environments do not display so much flexibility in collapsing and expanding threads. In expanded mode, the collaborative discussion trail can very easily be followed, also because unnecessary information is not displayed.

The design preserves an excellent overview to the user who is making a comment. Dividing the screen into three parts makes it possible to display the whole text, the line involved, and the comment that the user is working on, together on one screen. In most learning environments, if a user replies to a message, the screen refreshes, and a comment screen appears. Often, the messages to which the user replies are also visible, yet in a different location than it was before the user replied. There are no learning environments that show an overview of the whole discussion while the user is typing his or her reply.

8.2 Mobile collaborative learning – The Savannah project

Another example of technology supporting collaborative trails is the Savannah project (Facer et al., 2004). The aim of the project was to bring together mobile and game technologies and apply them to support collaborative learning and to explore whether these technologies could encourage the development of children’s conceptual understanding of animal behaviour.

The game takes part in of two related physical areas. In the first, children play at 'being a pride of lions' outside in a playing field (100m x 50m), interacting with a virtual savannah (through handheld devices) and exploring the opportunities and risks to lions in that space. Children are given GPS-linked PDAs through which they ‘experience’ the world of the savannah (through ‘sight’, ‘sound’ and ‘smell’) as they navigate the playing field. The second space, the 'den', is indoors and here the children reflect on their success in the game, can access other resources to support their understanding, and can develop strategies for surviving as lions in the virtual savannah.

”In order to 'sense' the savannah, children are given hand-held PDAs and headphones. Using these as they move around the playing field outdoors acting as lions, they hear the sounds of the savannah relating to the specific zones or wildlife there, they see still images of the environment and animals to be found in the zones, and they 'smell' the scents to be found in those zones, through still pictures of animal paw prints. On these PDAs, the children can also 'mark' specific information and send it back to the den for later analysis; in later levels they can also 'attack' specific features of the savannah. They also have an energy bar that lets them know their specific energy levels at any time. The PDA also receives messages sent by facilitators in the den - such as 'you are too hot', 'you are hungry' or on occasion 'you are dead - return to the den'.” (Facer et al., op. cit.)

The project team describe the technical support for the project as follows:

“Savannah is a client/server system in which the hand-held computers (iPAQ 5450) carried by the children/lions act as mobile clients to a PC-based game server. The mobile clients have integrated 802.11b wireless networking capabilities, a full colour screen, a sound system, 256mb of file storage containing all the images and sounds used in the game, and an attached GPS unit. These capabilities allow the mobile clients to:

- determine their locations in the outdoor game area
- accept inputs from the users in the form of button events ('mark', 'attack')
- transmit location information and user interface events to the remote game server over the wireless network
- accept responses from the game server that require individual clients to display a picture or a message, play a sound file or change the energy level shown on the client's screen.

The game server uses the information received from the mobile clients to determine what happens in the game and thus what the children/lions experience. For example, the server interprets incoming location information from the clients with respect to maps that relate the virtual savannah to the physical game space. As a result, the server may instruct a client to render a sound, image or scent that represents something that child/lion would encounter at that location in the virtual savannah, such as an angry elephant.”

Part of the analysis centred on video data of children playing Savannah and this revealed evidence that suggested that the children found the experience highly engaging and also that they identified strongly with being ‘lions’ and felt that they were experiencing many Savannah ‘features’. For example they talked as though they were directly experiencing the situation. This accords with Gee (2003)’s argument that “commitment to the identity within which one plays in a game is key to the games experience and that learning in these environments is characterised by self-motivated attempts to experiment, try out and reflect in the games world in order to overcome difficulties” (Facer et al., 2004, p1).

8.3 Revisiting collaborative trails – A field trip

Background

Field trips currently rely upon travel in groups to a remote location where study is undertaken and field notes are collected and compiled; the synthesis of that experience then takes place back in the class or seminar room. The use of wearable and mobile devices for recording data therefore can be regarded as a facilitator of field trip study and may provide new models for how study is moving away from desk-based research towards more proactive and experiential learning (Kolb, 1984) or to support collaborative action research.

Learner trails can support field study in a range of ways, whilst being facilitated by the use of mobile and wearable used in situ to gather information about the environment.

We can envisage a time in the not-too-distant future when all children will be able to integrate new approaches to learning through the use of innovative interactive learning tools and flexible learning and teaching methods that can both promote individual and collaborative learning, whilst encouraging reflection through the use of virtual and real data collection. The learner trail in the field study scenario may facilitate a more personalised learning experience, whilst also allowing children to work together. The different modes of presentation allow the child to share the learning experience with their parents, friends, teachers and other students, allowing for formal and informal learning outcomes to be considered as reinforcing modes of learning. In this way, learner trails that make use of hypertexts, computer simulations and handheld devices will support and enrich the learner’s experience whilst supporting the wider learning objectives of the education system.

The scenario

One class of schoolchildren go out on a one-day field trip to collect geographical data to feed into a collaborative class project. The trip is to the coast and students are required to dissect the beach into squares for observation taking samples at regular intervals to produce a cross-section of the beach that can then be computer-modelled back in the classroom using interactive whiteboards and personal computers connected by networks.

The field study involves the individual students entering the data collected via dedicated software onto the wearable and mobile device that includes a range of functionality including environmental sensors (e.g.: a 3D camera), field study evaluative software (e.g.: graphical database, search facility), connection to the online digital libraries and research databases and GPS tracking facilities. The data collected by the students may include digital information collected such as: 3D photos of the beach, voice recordings of pupil observations and class discussions, 3D digital video clips and written or spoken field notes. The data collected might also include physical material such as: field drawings of samples and actual samples of rocks, sand, water and plant life, which is scanned by 3D scanners and input into the wearable or mobile device.

The data, once collected, can be taken back to the school classroom or home where the data from all the children can be filtered and entered into a database. The information, including information about the position of the beach, the contents of the beach, its aspect, rock formations and sedimentary make-up then becomes part of an interactive, digital computer simulation which can then be explored by all the students individually using their own handheld PCs or by the class using the interactive whiteboard. The tutor will facilitate discussion about the field study, asking leading questions, relating learning content to the study and indicating methods used. The data can also be displayed in a number of different graphical and textual modes, allowing children with different learning styles to manipulate the information in a method that best suits their own personalised needs. For example, the simulations can be viewed as an interactive hypertext added to the student’s personal learning web site and used to form a basis for discussion between the student and their teacher and parents. The hypertextual form can also be used to inform homework assignments and provide the basis for reflective discussion later in the term or in relation to another field study made.

For example, the data collected from the field trip can be visualised either in the form of an adaptive learner trail or used to form the basis of the classroom project. In the latter case, the data collected from the cross-section beach field study including photos, movie clips and field study data can be used to produce a three-dimensional interactive simulation model. This model can be interacted with both individually as part of the hypertext and collaboratively through the interactive whiteboard. The simulation can then be used to promote dialogue between the children, the tutor and parents, promoting an engagement between formal and informal learning outcomes. Dialogic modes of communication can be used to debrief the students, to make overt key issues and to reflect upon the learning process itself. Through this process the student can reflect upon what they have learnt and explore the information interactively thereby promoting higher order cognitive development and supporting Kolb's experiential learning cycle (Kolb, 1984), through allowing students to experience – reflect – consider – test. This mode of learning can support a complex engagement of learning that links between the real and the virtual supporting higher cognitive development through creating links between the lived experience and abstract reflection.

The individual can make use of the hypertext generated as part of his or her own formative learner trail, which provides a learning pathway that can be altered and adapted. Students can also refer back to the hypertext, share information with other learners and create presentations based upon the trail. The trail in this context is both an individual learning trail (as each child can see their own contribution separately from that of the class) and a collaborative trail (as the collated experimental work can be viewed and interacted with as a basis for group work). The reinforcement of teamwork is enforced through computer based collaborative work enriching the learner's individual experience and providing a group context within which to reflect upon and discuss learning outcomes after the field study has been completed.

The post-field study debrief allows the group to discuss and debate the project in detail, through use of interactive whiteboards and computer simulations using class discussion and debate to analyse and reflect upon what has been learnt and to become more analytical about how to source and evaluate data. In addition the students have time to reflect upon particular methods for study, reinforcing metacognition. In this way, the learning outcomes include a lived experience of geographical field study, an introduction to the methods of approach used by geographers and geologists, working together in a team and deeper critical reflection upon their own contribution to studying the physical environment.

9 Concluding remarks

We have seen throughout this deliverable many of the different forms that collaborative trails can take and how their use can be supported by various technologies that can help the learner to learn or the instructor to assess learning. The main (although not exclusive) focus has been on collaborative trails that occur within CSCL environments when learners work together to achieve a common learning goal.

As we have seen, the theoretical and psychological underpinnings of such collaborative work as expounded in the theory of constructivism provide a solid basis for the design of CSCL environments. The thorough survey we have presented of systems that are currently available shows that some of the necessary functionality to support collaborative work is beginning to be provided, but the best of these systems are still experimental and so there remains much to be brought to the marketplace in terms of technology and expertise. We have concluded the document by trying to give a feeling for the kinds of technology-supported collaborative scenarios that may become an everyday reality in the near future, in order to really “explore the future of learning with digital technologies”.

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