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Design of web-based collaborative learning environments. Translating the pedagogical learning principles to human computer interface

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Abstract

Seven pedagogical principles guided the development of a collaborative virtual environment, within an international project called ITCOLE. The progressive inquiry model as a theoretical framework had a large impact on describing these principles. Furthermore, this article describes the two web-based software systems – Synergeia and FLE3 – that were developed in the project. Teachers evaluated this software in the light of two perspectives: user friendliness (ease of use) and user satisfaction (especially the pedagogical usability). It is concluded that the participants find the software easy to use. The user satisfaction ranges between good and average. Details about the different types of evaluation are reported in the paper.

Keywords: Architectures for educational technology system; Cooperative/collaborative learning; Distributed learning environments; Interactive learning environments; Pedagogical issues

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1. Introduction

The development of information and communication technology (ICT) is changing the way in which people work, communicate and learn. Co-operative and collaborative environments will allow group work, group conferences or joint effort in knowledge building. Nevertheless, technological possibilities, instead of pedagogical principles often lead the development of virtual learning environments (Rubens, 2003). This has led to disappointing results in the past. Recently pedagogical principles are leading in the development of virtual learning environments. According to Simons (2003), the time is finally ripe for "digital pedagogy".

In the ITCOLE-project[1] pedagogical principles were the fundaments of the development of web-based Collaborative Learning Environments (CLEs). One of the main challenges in the ITCOLE-project was the design and development of collaborative software systems that maintain the (synchronous/asynchronous) collaboration and that can be integrated in a web-educational environment.

This article describes these pedagogical principles. Furthermore, it introduces the software developed and it presents the evaluation results of the software.

2. Pedagogical principles for software development

The development of the ITCOLE software was based on an extended analysis of current practices of using computers in European educational contexts (Lakkala, Rahikainen, & Hakkarainen, 2001b) and on analyses of functionality and interfaces of existing computer software for collaborative learning and collaborative work (Kligyte & Leinonen, 2001). The analysis of these practices was based on information about the use of Internet and networked learning environments for instructional purposes in the participating countries. As a result of this analysis thirteen principles for designing web-based Collaborative Learning Environments (CLEs) were formulated (Lakkala et al., 2001b). These principles were not related to the development of the software exclusively. According to the ITCOLE researchers the design of a CLE is only partially a software design challenge. It is also a matter of designing appropriate pedagogical and epistemological infrastructures. Within the scope of this article we will only address the most relevant pedagogical principles, related to software development.

The functionality and interfaces of existing software dedicated to collaborative learning systems (Kligyte & Leinonen, 2001) were studied and used by the interface designers involved in this project. This constituted the starting point for the development of new web-based software devoted to international and multi-domain activities. The study analysed 19 different software designs, used for both collaborative work and learning. Under the labels of both Computer Supported Collaborative Learning and Computer Supported Collaborative Work (CSCL/CSCW), there are a considerable number of software and computer platforms, but the nineteen systems selected for closer

[1] ITCOLE stands for Innovative Technologies for Collaborative Learning and Knowledge Building. The project was funded by the European Union in the IST program, IST-2000-26249.

analysis were considered to be a representative sample of all different systems (Kligyte & Leinonen, 2001).

2.1. Designing for flexibility and modularity

Since there is a variety of pedagogical cultures and practices in the participating countries, it was estimated that the design of the ITCOLE software should be characterized by flexibility and modularity. The functionality and interface of the system would be derived from pedagogical considerations and could be adapted to the different school environments and contexts as well as used in conjunction with other pieces of software. Moreover, adaptation to various national pedagogical cultures and different educational contexts was needed. Therefore the creation of a modular learning environment was suggested, so that the users were able to select the modules they could use in the context of each project. According to Lakkala et al. (2001b) this could be called *pedagogical usability*, i.e., correspondence between the system's design and the educational environment, situation, and context in which it will be used.

2.2. Facilitating knowledge building rather than providing a discussion forum

By synthesizing different ideas of cognitive research (e.g. Brown & Campione, 1996; Scardamalia & Bereiter, 1994) a framework for progressive inquiry was expanded and elaborated (Hakkarainen, Järvelä, Lipponen, & Lehtinen, 1998). In brief, this model could be described as a sustained process for advancing and building the type of knowledge needed for scientific inquiry. It entails that new knowledge is not simply assimilated but constructed through solving problems of understanding (knowledge building). Characteristic of this kind of inquiry, instead of direct assimilation, is that the student treats new information as something problematic that needs to be explained (Bereiter & Scardamalia, 1993; Chan, Burtis, & Bereiter, 1997). By imitating practices of scientific research communities, students can be guided to engage in extended processes of question- and explanation-driven inquiry. An essential aspect of this kind of inquiry is to engage collaboratively in the improvement of shared knowledge objects, i.e., hypotheses, theories, explanations, or interpretations (Scardamalia & Bereiter, 1996). Through intensive collaboration and peer interaction, resources of the whole learning community may be used to facilitate advancement of inquiry (Hakkarainen, Rahikainen, Lakkala, & Lipponen, 2001). In the ITCOLE-project the model of progressive inquiry was the leading pedagogical framework (Emans & Sligte, 2003; Lakkala et al., 2001b; Rubens et al., 2003; Stahl, 2002). Besides, another pedagogical principle for the development of the ITCOLE software was the requirement of models and tools that help the participants to develop and share knowledge, to store knowledge and experiences of individual teachers and students, and their projects in order to create a collective memory (see De Laat & Simons, 2002). Instead of regular discussion forums, support for knowledge building had to be provided. Participants should be allowed to identify key ideas, to take them for further elaboration, and build on to them. In terms of software design, fostering knowledge building entails the system to allow and encourage the users to develop shared digital artifacts in addition to engage in knowledge-building discussions. The ITCOLE software had to provide tools that support the process of collaborative design and elaboration of digital artifacts.

2.3. Scaffolding progressive inquiry

As a consequence of applying the progressive inquiry model, the importance of using a category of inquiry labels, to support the inquiry processes within the ITCOLE software, was addressed (based on the practices of Scardamalia & Bereiter, 1993). Knowledge building should be facilitated with knowledge scaffolds that will help students to get into the inquiry processes, in this way supporting knowledge advancement. Users' participation was structured by asking them to label their messages according to a category of inquiry. When these categories were properly used, the participants' inquiry process was scaffolded and support was offered to engage in higher-level cognitive processes (Lakkala et al., 2001b). This design feature was based on the theory that the educational use of these kinds of labels supports the management of a relatively large number of messages in the databases, handles the threaded structure of discourse, and also facilitates community-building (Baek, Liebowitz, Prasad, & Granger, 1999; Häkkinen, Järvelä, & Dillenbourg, 1999; Ogata & Yano, 1998).

The researchers emphasized the importance of having coherent sets of inquiry categories rather than only individual – random – categories. Therefore so called "thinking types" were used to support progressive inquiry, although the researchers also addressed the importance of having fully editable inquiry categories that could be tailored to different pedagogical contexts. Thus, besides the progressive inquiry thinking types also other sets of thinking types were and could be used.

2.4. The role of tutoring in progressive inquiry

Since active engagement of the tutor is an important condition for facilitating progressive inquiry (Lakkala et al., 2001a), the ITCOLE software should be equipped with Tutor Tools that would enable printing the students' productions and summarizing advancements of inquiry. According to the researchers it is important to create tools that will help to provide summaries of discussions and each student's contribution during a task, and, therefore, help a tutor to get an overview of what is going on in the CLE.

Furthermore, the researchers expected that synchronous tools could provide important new possibilities for situated and dynamic guidance that would not be possible in asynchronous systems alone.[2]

2.5. Providing tools for structuring and coordinating activity

According to Lakkala et al. (2001b) an important pedagogical principle was the simultaneous provision of structures that would help students to coordinate their collaborative activities and guide them to reach a series of milestones rather than to be left on their own. A great deal of coordination and structuring was needed in order to support adequate participation and to guide students to engage in in-depth inquiry. Therefore, the ITCOLE software should contain coordination tools that help a teacher, tutors, students and their teams to set up main goals and sub-goals

[2] These tools were developed during the ITCOLE-project, although they were ready to use when the research was done. So, the use of these tools was not evaluated.

concerning their investigations. For example a space for setting up a time table, milestones and shared goals of projects as a whole as well as corresponding aspects of a team's or individual students' inquiry.

2.6. Designing tools for process analysis

Sophisticated tools that allow students and teachers to follow their progress in the inquiry process were needed. For the researchers and designers of the ITCOLE software these tools also should provide statistical information about the usage of different tools and functionalities of the software.

2.7. Providing support for community building

Based on a literature study (Häkkinen et al., 1999; Jermann, Soller, & Muehlenbrock, 2001; Munro, Höök, & Benyon, 1999; Schlichter, Koch, & Chengmao, 1998) the ITCOLE researchers emphasized the importance of developing tools that help a partially or completely virtual community to manage their collaborative activities, build their community, and achieve mutual understanding (Lakkala et al., 2001a, 2001b). The software should support users in developing a sense of community and belonging, even in cases when they are distributed across space and time (developing a sense of belonging, re-creating one's identity in relation to the virtual community, and by building shared histories).

In Section 3.4 we will relate the pedagogical principles to the developed ITCOLE software.

3. ITCOLE software

In the ITCOLE project two applications were developed: Synergeia and FLE3. For Synergeia and FLE3, synchronous functionalities were developed separately, under the name of MapTool. In this section we will describe these applications. First we will pay some attention to the software development process. The concluding paragraph presents the relationship between the pedagogical principles – described above – and the developed ITCOLE software.

3.1. Software development

Before the design and integration of the new system, the technical partners of the ITCOLE project studied several collaborative environments, analyzing what features should be offered and what communication system fits with the necessities in the ITCOLE research (Kligyte & Leinonen, 2001).

Dealing with synchronous features it is necessary to introduce items such as session management, synchronous and asynchronous collaborative components support, an extensive coordination model and awareness and monitoring systems.

According to the communication models that were analyzed, the hybrid model was ideal for our design. More concretely, this model combines synchronous communication with asynchronous communication.

In the ITCOLE project a software development method was applied, called Extreme Programming (Beck & Fowler, 2001). Furthermore basic principles of Participatory Design were used (Avison & Fitzgerald, 1995).

An important quality of this approach is intensive interaction with the target group. In this project programmers collaborated with pedagogical researchers (face to face and online) about the software requirements (based on the pedagogical principles). The programmers developed a first version that was tested in schools. Teachers and students wrote user stories that were used to generate requirements for the second version. In a user story a user wrote about the purpose of an activity within the environment, the activity itself and what he or she experienced. Of course, because of constraints such as limited resources (e.g. time, money), it was not possible to implement every end user requirement. Within the scope of this article this model will not be elaborated in detail (see, for example, http://www.extremeprogramming.org).

3.2. Synergeia

The first software, that was developed, was Synergeia. Synergeia is an extension of BSCW (Basic Support for Cooperative Work). BSCW (Basic Support for Cooperative Work) enables collaboration over the Web. BSCW is a "shared workspace" system which supports document upload, event notification, group management and much more. Built on BSCW, Synergeia adapts this system of shared workspaces to create virtual places for learners to work and collaborate in groups.

In Synergeia learning places are typically arranged as a series of perspectives:

- a personal perspective in which a student can develop his or her own initial thoughts and assemble ideas from others or materials from the Web;
- a group perspective that is shared in a workgroup;
- a course perspective, where ideas and materials can be discussed with all course participants.

These perspectives have special features and access rights to help them work naturally in school settings without putting a major burden on teachers to design and set up such structures.

Synergeia combines features of two types of electronic learning environments: it consists of communication tools, and empty spaces to allow the teacher to create and shape his courses. But it also offers shared workspaces and document sharing from the collaborative workspaces.

An important functionality of Synergeia is the knowledge-building option (Fig. 1). Knowledge-building proceeds largely through interaction. Therefore, each perspective (personal, group and course) automatically contains a threaded discussion component which is scaffolded with a set of thinking type categories for the notes. Before someone can enter a note, the decision has to be made what category of note a user wants to add to the existing discussion (Stahl, 2002).

MapTool is one of the synchronous tools that have been incorporated in Synergeia (Fig. 2).[3] It consists of a whiteboard and a chat tool. In this tool synchronous and asynchronous features have been incorporated. For that reason, any user can obtain and modify the result of a previous collaboration although he was not collaborating in the building process of this information.

As an integrated tool the MapTool requires information from Synergeia to be able to carry out some operations inside each system and to establish the connection to the corresponding session.

[3] MapTool was developed to be integrated in Synergeia and FLE3. At the time the research was carried out integration of MapTool in FLE3 was not implemented.

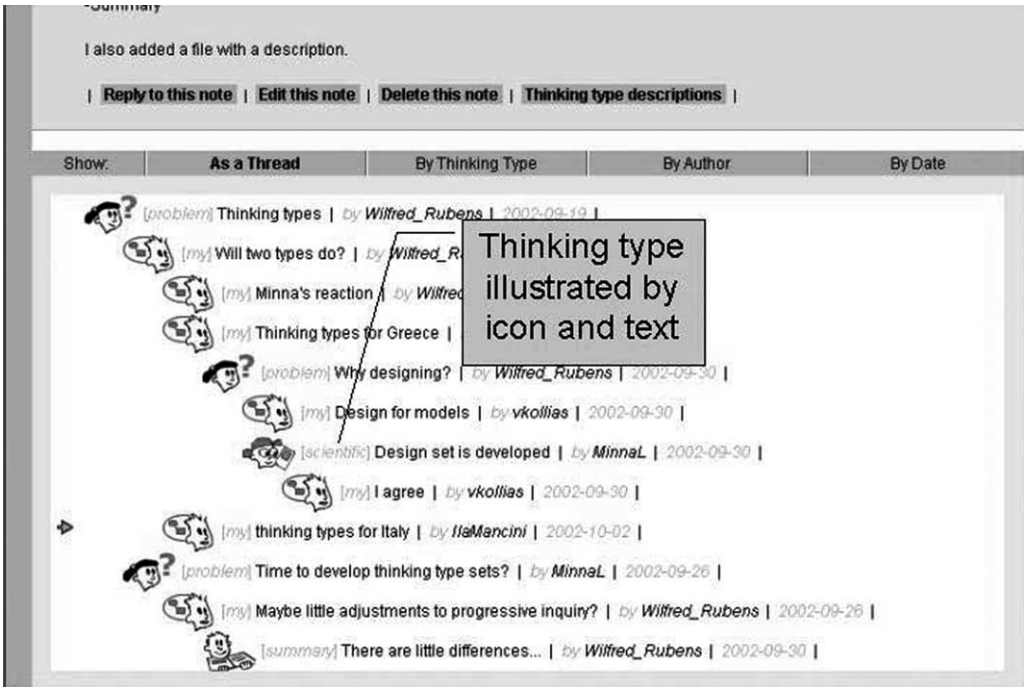
I also added a file with a description.
Reply to this note | Edit this note | Delete this note | Thinking type descriptions
Show: As a Thread By Thinking Type By Author By Date
[problem] Thinking types | by Wilfred_Rubens | 2002-09-19 |
[my] Will two types do? | by Wilfred_R
[my] Minna's reaction | by Wilfred
[my] Thinking types for Greece |
[problem] Why designing? | by Wilfred_Rubens | 2002-09-30 |
[my] Design for models | by vkollias | 2002-09-30 |
[scientific] Design set is developed | by MinnaL | 2002-09-30 |
[my] I agree | by vkollias | 2002-09-30 |
[my] thinking types for Italy | by IlaMancini | 2002-10-02 |
[problem] Time to develop thinking type sets? | by MinnaL | 2002-09-26 |
[my] Maybe little adjustments to progressive inquiry? | by Wilfred_Rubens | 2002-09-26 |
[summary] There are little differences... | by Wilfred_Rubens | 2002-09-30 |
Thinking type illustrated by icon and text

Fig. 1.

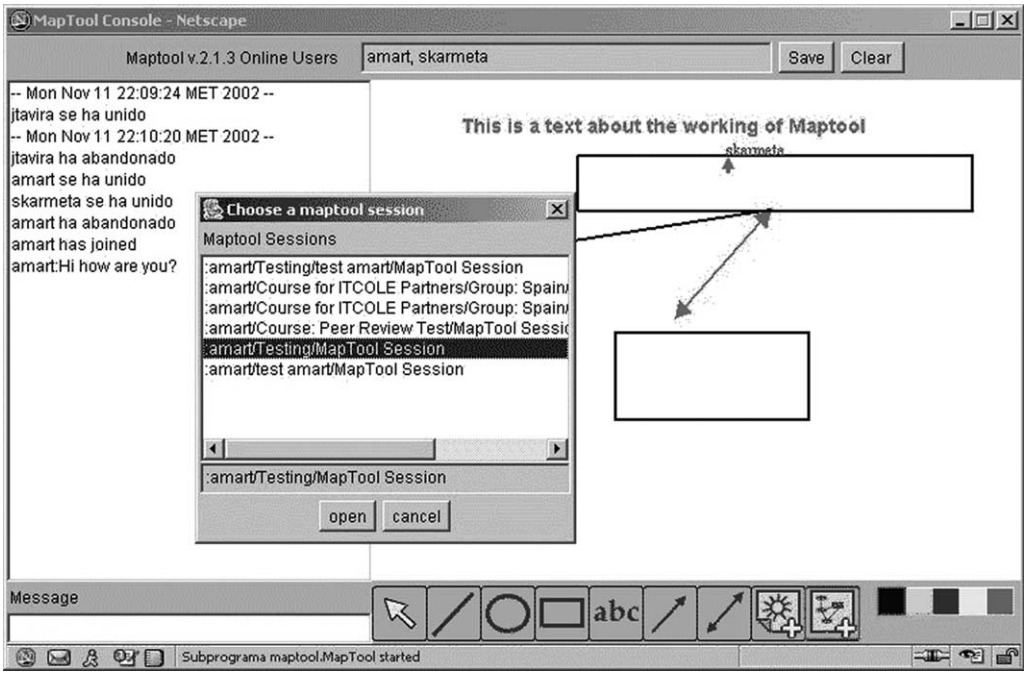
MapTool Console - Netscape
Maptool v.2.1.3 Online Users
amart, skarmeta
Save
Clear
-- Mon Nov 11 22:09:24 MET 2002 --
jtavira se ha unido
-- Mon Nov 11 22:10:20 MET 2002 --
jtavira ha abandonado
amart se ha unido
skarmeta se ha unido
amart ha abandonado
amart has joined
amart:Hi how are you?
This is a text about the working of Maptool
skarmeta
Choose a maptool session
Maptool Sessions
:amart/Testing/test amart/MapTool Session
:amart/Course for ITCOLE Partners/Group: Spain
:amart/Course for ITCOLE Partners/Group: Spain
:amart/Course: Peer Review Test/MapTool Sessio
:amart/Testing/MapTool Session
:amart/test amart/MapTool Session
:amart/Testing/MapTool Session
open
cancel
Message
abc
Subprograma maptool.MapTool started

Fig. 2.

When dealing with asynchronous features, this tool is activated in a course with a MapTool. It restores the previous session by invoking a method in the educational environment which returns the MapTool file to the latest status. In order to maintain the latest changes made in the MapTool, the final status will be saved automatically. As any synchronous tool this application has to follow some features in order to be able to maintain a coherent communication:

First, with the aim of keeping the flexibility condition when a user connects to the system, the actual status in the active session has to be send to the new user. All the users in the same session have to be able to see the same data independently of the time they log-on. In this way this tool allows late comers in the system.

Second, in order to know who is responsible for the actual drawing in the whiteboard there is a tele-pointer which consists of a red arrow and the user name (workspace awareness). Users can also see who is joining a MapTool session (presence awareness).

With the aim to encourage the internationalization, the MapTool receives from the educational environment the user language and it loads the corresponding labels for this language.

In order to solve the synchronization problem of the shared area, it has been decided from a the pedagogical point of view that all the users can have access to it at any moment but only one of them can manage a specific object.

Following the same architecture principles as in the MapTool, it has developed into another tool which allows users to send messages between them, avoiding that all the users in the session can see them. This tool, called Instant Messages, has only been integrated in Synergeia. This tool is an applet as well, and it loads its configuration based on the information received from Synergeia.

With the purpose to facilitate the view of how a MapTool session has been built, it has been implemented a tool called TutorMapTool which shows the changes made in a session using a time scale, similar to any video player. This tool also allows saving the result of the monitoring activity in files that can help in a posterior analysis, saving all the events of the actual monitoring, as well as saving only a part of these events.

In addition, it incorporated the option to retrieve data by using dates. In order to show how the users have been collaborating in Synergeia, it has implemented a web tool called MapToolLog which shows this data in a graphic mode as well as in a table mode.

Using Synergeia, teachers have many options for structuring projects or courses. They can also choose among several sets of thinking types in different knowledge building areas. Students can also use many features to structure their own group work. To provide a more personal appearance of the computer screen, photos of the students are prominently used to indicate whose workspaces or remarks are displayed. Synergeia shows extensive history reports and it displays lists of all members of a folder, with indications of each member's level of activity, for example, whether they are using synchronous tools at that time.

In the typical working scenario of Synergeia teachers register their students or other colleagues to the system. They create courses and enrol the students to these courses. In a course the teachers are able to form working groups among the enrolled students. In a group a teacher may setup an initial discussion for knowledge building. If students are logged in to the system, they will see their home area with their personal perspective and the courses in which they are enrolled. In a course they will find the working groups, in which they have to perform their knowledge building tasks. By entering a group they can join or start a discussion for knowledge building. They may also start or join a MapTool session to explore their ideas synchronously in a conceptual map. If they are

finished with their tasks, the students can copy their results in the course perspective to present these to, or discuss these, with their course members.

3.3. FLE3

The second application, which was developed in the ITCOLE-project, was FLE3. FLE3 is designed for group-centred work that concentrates on creating and developing expressions of knowledge (i.e. knowledge artefacts). The knowledge creation takes place in a shared working space where students carry out progressive discourse interaction and add their knowledge artefacts to the database (Leinonen, Kligyte, Toikkanen, Pietarila, & Dean, 2003).

FLE3 consists of modules that are designed to facilitate collaborative knowledge building and collaborative design work. The modules are: a user's WebTop (virtual desktops), a Knowledge Building module and a Jam Session module. The staff users, who take care of the courses and course participants, have tools for managing users, courses and participants of the courses (Leinonen et al., 2003).

Each user of FLE3 gets a personal WebTop. WebTops can be used to store different items (documents, files, links to resources in the web, link to knowledge building notes and jam session artefacts) related to the studies or project and to organize them into folders. The WebTop is the teachers and the students "digital desktop" and "bookshelf" for their studies. The WebTop is not trying to fulfil all different data storage needs of the users, but it focuses on the data related to the users study work. The items in the WebTops are shared with other users in the same course or project, as users may visit each others' WebTops. The users can also find items in other people WebTops by using the FLE3 search engine. The openness of the WebTops implements the idea of open office space where people working in a same office can go and visit each others' work space, have a look at the books, documents and folders in there and take copies of them if agreed so. The open WebTops rely on trust and agreements between the users sharing a project with each other. With the WebTop users may create their own knowledge databases. Teachers and students may create their own categorization of information by naming folders. Inside the folders they may then include notes from Knowledge Building (alias), artefacts from Jamming or materials found from the web. The categorization and organization of information is made by themselves and different categories may include materials from different courses and classes. The categorization of information by naming things is seen as one important activity of learning. Only the owner of a WebTop may create, edit and remove items in his or her WebTop, but visitors may read the items and take copies. The WebTop also includes a shared "course folder" for each course or collaborative project. The shared folder is available in the Knowledge Building and Jamming modules as well (Leinonen et al., 2003).

With the Knowledge Building tool, groups may carry out knowledge building dialogues, theory building and debates by storing their thoughts into a shared database. The knowledge building discussion is scaffold and structured by knowledge types, which label the thinking mode of each discussion note. The Knowledge Building tool contains two default "knowledge type sets": (1) Progressive Inquiry and (2) Design Thinking.

The procedure is similar to the one in Synergeia (see above). To help writing contributions to the knowledge building, FLE3 offers a checklist explaining the participants how to structure the note in order to advance the learning process. For example, when writing a New Information – note in the design knowledge building the "Flea agent" asks the author: "Does the note present some new information related to the design task? Remember to mention the source where you got

the new information: – by interviewing users – by analyzing the design context? – by studying earlier design solutions of others. As an aid for users to follow the knowledge building discussion and process, users may take different views to the knowledge building database by sorting the notes as a discussion thread, by writer, by knowledge type or by date. An advanced search engine for the knowledge building allows searching the database of notes by title, author, course context or words used in the note (Leinonen et al., 2003). These options are similar to the ones in Synergeia.

The Jamming tool is a shared space for collaborative construction of digital artefacts (e.g. pictures, text, audio, and video). A study group may work together with some digital artefacts by simply uploading and downloading files. Versions are tracked automatically and different versions are displayed graphically. Users may also add annotations to artefacts. When setting up a jam session the tutor may choose from three types of jam sessions: (1) "mutate on previous" or (2) "explore possibilities" and (3) "diverge and converge". This gives the users slightly different possibilities to make new versions and to make references to earlier versions. Originally the Jamming tool was designed for visualizing ideas in a group. However we have noticed that Jamming could be used for many different kinds of collaborative design work that requires versioning. The artefacts used in this process can be text, picture, poster, music, video, animation, multimedia or a piece of software (Leinonen et al., 2003).

The staff users which take care of the courses and course participants have tools for managing users, courses and participants of the courses. With the user management tools, staff users may add new users manually or invite them via email. With the course management tools staff users may add users to courses with a role of student, tutor or teacher in the particular course. Furthermore

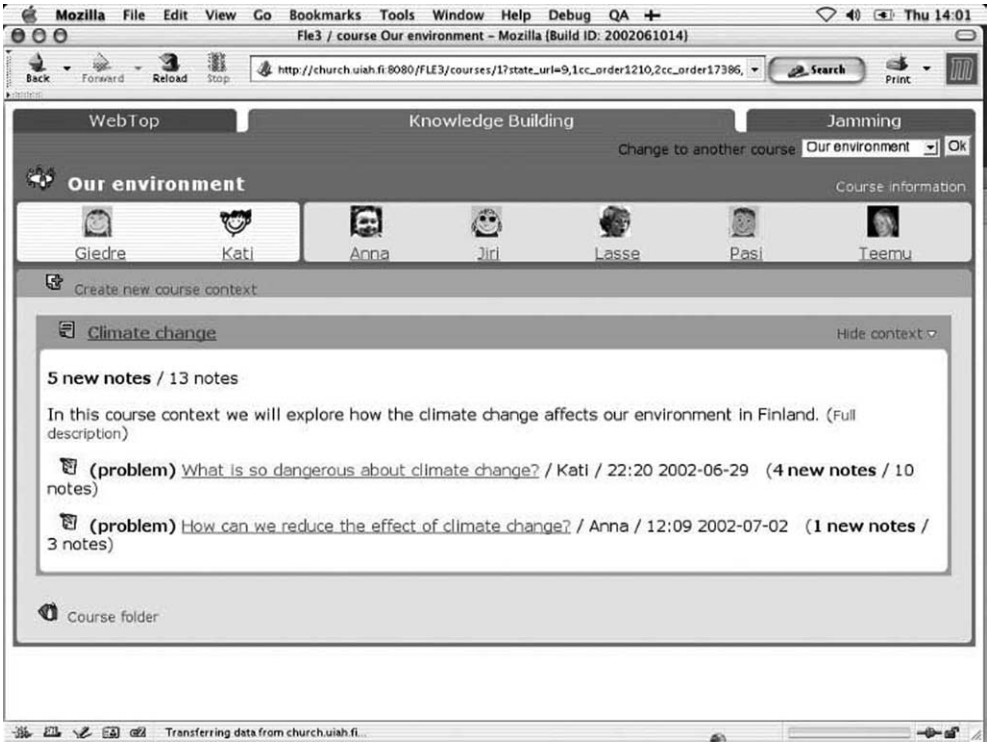

Fig. 3.

staff users may manage the knowledge type sets, create new ones, copy and edit existing ones and export and import them between FLE3 systems (Fig. 3) (Leinonen et al., 2003).

3.4. Pedagogical principles applied in ITCOLE software

Table 1 provides a summarized overview of the relationship between the described pedagogical principles (see Section 2) and the functionalities of the developed ITCOLE software. It is important to consider that MapTool was integrated in Synergeia.

Table 1
Relationship between pedagogical principles and the functionalities of the developed ITCOLE software

	Synergeia	FLE3	MapTool
Designing for flexibility and modularity	• Personal/group/course (project) levels (spaces) • Opportunity for teachers and students to structure content in different ways • The ability to define own sets of thinking types • Available in different languages	• Personal/group/course (project) levels (webtop) • Opportunity for teachers and students to structure content in different ways • The ability to define own sets of thinking types • Available in different languages	• Opportunity to start a session on group and course (project) level • Obtain and modify previous collaboration • Option to come late
Facilitating knowledge building	• Separate KB-functionality • Different sets of thinking types	• Separate KB-functionality • Jamming functionality • Different sets of thinking types	• Whiteboarding and chat
Scaffolding progressive inquiry	• Use of thinking types, based on progressive inquiry	• Use of thinking types, based on progressive inquiry • Flea	
Role of tutoring in progressive inquiry	• Option "summary" and "evaluation" in KB • Option of sorting contributions • Ability to copy and paste artifacts	• Option "summary" and "evaluation" in KB • Option of sorting contributions • Ability to copy and paste artifacts • Flea	
Providing tools for structuring and coordinating activity	• Calendar • History reports • E-mail functionality (individuals or group)		• Instant messaging • Tele-pointer
Designing tools for process analysis	History reports		TutorMapTool MapToolLog
Providing support for community building	• Personal appearance computer screen • Pictures of members • Visibility active users • Display list of members • History reports	• Open webtop • Pictures of members • Visibility active users • Display list of members	• Visibility active users • Instant messaging

Table 1 illustrates that the two environments provided for support related to all of the seven pedagogical design principles. The differences between Synergeia and FLE3 refer mainly to the final three principles: the tools for structuring and coordinating activity, for process analysis and the support for community building differ.

4. Evaluating pedagogy and technology interaction in the ITCOLE software

Within the ITCOLE project, both technical aspects and technological features of the software were evaluated. The pedagogical aspects of the projects are described in the other papers included in this special issue. In this article, the evaluation of technological functionalities will be discussed, together with the interaction between pedagogy and technology. The following research questions will be answered:

I. Is the system easy to use from the viewpoint of the teachers (user friendliness)?
II. Are the involved teachers satisfied by the functionality provided by the system?

The first research question deals with the user friendliness of the software systems. The second research question is concerned with the more basic principles of user satisfaction with respect to the various functionalities provided by the software systems. The pedagogical usability is an important aspect of the user satisfaction of teachers.

4.1. Method

Since two software systems were tested (Synergeia and FLE3 – MapTool was included as a tool in Synergeia), answering the research questions within the boundaries of the ITCOLE project was a complicated affair. To evaluate each system, two general questionnaires have been used to gather quantitative data (one questionnaire for teachers and one for students). This article focuses mainly on the quantitative analysis of the teacher questionnaires (Emans & Sligte, 2003). The questionnaire was tested at an early phase of the ITCOLE-project, evaluated and finalized.

Synergeia was used in three countries (Italy, Netherlands, and Greece) and the questionnaires administrated, were related to the technological and pedagogical usability of it. FLE3 was only used by the Finnish teachers (Table 2).

Table 2
Overview of participating teachers per country

	Primary education	Secondary education	
Finland	7	Lower s.e.: 4 Higher s.e.: 4	15
Greece	2	7	9
Italy	11	6	17
Netherlands	11	6	17
	31	27	58

4.2. Results for Synergeia

4.2.1. Technical usability

Teachers were asked to give an overall rating of Synergeia on seven aspects. The answers could vary between (1) "very bad" and (6) "very good".

On average, the teachers are positive about Synergeia. It is easy to use ($M = 4.53$; SD = 1.09), and in general it is easy to go to the places you want to go to within Synergeia ($M = 4.29$; SD = 1.03). Screen design and information presentation are good ($M = 4.4$; SD = 0.84 and $M = 4.37$; SD = 0.89), indicating that items are at the right place on the screen, and that the information is presented clearly, although one teacher states that the user screen should have less buttons. The functionalities could be placed in the existing menus. Overall, teachers think that Synergeia has a good aesthetic value (indicating beauty or elegance) ($M = 4.05$; SD = 0.95). The least positive are teachers about the attractiveness for students ($M = 3.85$; SD = 1.19). The overall functionality of Synergeia is good ($M = 4.39$; SD = 1.02). There are no significant differences in the overall view on Synergeia between teachers in primary and secondary education. In general, The Italian teachers seem to be the least positive and Greece' teachers seem to be the most positive. The teachers were also asked to rate the technical usability of the functionalities within Synergeia. The rating is on a six-point scale.

The participating teachers are positive about the technological usability of the functionalities within Synergeia. Setting up a course ($M = 4.95$; SD = 0.89), creating groups ($M = 4.74$; SD = 0.95), uploading documents ($M = 4.82$; SD = 0.97), knowledge building area ($M = 4.87$; SD = 0.92), thinking types ($M = 4.39$; SD = 1.20), inviting people for a course or group ($M = 4.50$; SD = 1.08), and calendar ($M = 4.15$; SD = 1.20) have good scores. The MapTool ($M = 3.57$; SD = 1.55), instant messaging ($M = 3.64$; SD = 1.71), and the address book ($M = 3.77$; SD = 1.03) score only just above the average value of 3.5. The answers on the open questions in the questionnaire illustrate that not all teachers have used all functionalities. Some teachers were hampered by technical difficulties. For example a slow connection with the Internet makes it quite difficult to make use of all functionalities. Other teachers only used a few functions, as they first wanted to get used to these functions (mostly the uploading of documents and website, the knowledge building area, and sometimes the use of groups). Tools like the MapTool, instant messaging and the calendar they planned to use later on. Some teachers claim that due to security reasons, not all functionalities could be used at the school computers.

Additional analyses have shown that there is a difference in the evaluation of thinking types between primary and secondary schools ($P < .01$). Primary school teachers think that the thinking types function better in a technological way. Beforehand, we expected that this functionality might be too difficult for primary schools, but this turns out not to be the case.

4.2.2. Pedagogical effectiveness

Teachers were asked to rate the pedagogical effectiveness of functionalities of Synergeia on a six-point scale, ranging from (1) "very bad" to (6) "very good". In Table 3, the mean values per country are listed.

Again, the functionalities MapTool and instant messaging are rated low, mainly due to a negative evaluation of the Italian teachers, and a (relative) absence of the Greek teachers. It might be that these more negative evaluations are due to a limited technical usability. However, both tools are still around the average-point of 3.5, indicating that they are somewhat useful for pedagogical

Table 3
Pedagogical effectiveness of functionalities within Synergeia, reported per country

Functionality	Greece			Italy			The Netherlands			Total		
	M	*N*	SD	*M*	*N*	SD	*M*	*N*	SD	*M*	*N*	SD
Groups	*5.75*	8	0.46	*4.82*	17	1.43	*5.00*	15	1.07	*5.07*	40	1.19
Uploading of documents, URL's etc.	*4.86*	7	0.69	*4.76*	17	1.09	*4.41*	17	0.87	*4.63*	41	0.94
MapTool	*3.60*	5	1.67	*2.58*	12	1.68	*4.14*	14	0.95	*3.45*	31	1.52
Instant Messaging	–	–	–	*2.75*	12	1.77	*4.73*	11	1.10	*3.70*	23	1.77
Knowledge building area	*5.63*	8	0.52	*4.81*	16	0.98	*4.82*	17	1.02	*4.98*	41	0.96
Thinking types	*4.60*	5	0.89	*4.07*	15	1.28	*4.69*	16	1.20	*4.42*	36	1.20
Address book	*5.50*	8	2.51	*4.94*	17	3.58	*3.91*	11	2.12	*4.75*	36	2.96
Calendar	*5.13*	8	2.80	*4.82*	17	3.64	*4.45*	11	1.81	*4.78*	36	2.94

means. The address book had a slightly worse evaluation for the technical usability, but teachers rate the pedagogical usability of this tool as good. Additional analysis have shown that the calendar has a higher pedagogical value in secondary education, compared to primary education ($P < .05$). Finally, teachers were asked to give their opinions about four statements on collaborative learning in combination with Synergeia. They had to rate these statements on a six-point scale, ranging from (1) I fully disagree to (6) I fully agree.

In general the teachers are very positive about collaborative learning and the role of Synergeia in the process of collaborative learning. The statement "Synergeia supports collaborative learning" and "Seeing each other's notes in Synergeia helps students reasoning on their ideas" have high scores ($M = 5.27$; SD = 1.14, respectively $M = 5.12$; SD = 1.10). Teachers are also very positive about using Synergeia and principles of collaborative learning in their future classroom activities, indicating that both the software as the ideas behind it are sustainable beyond the scope of the ITCOLE project. The statements "In the future, I will use collaborative learning in my classes" and "In the future I will use Synergeia in my classes" have positive scores ($M = 5.46$; SD = 0.90, respectively $M = 4.90$; SD = 1.18).

4.3. Results for FLE3

4.3.1. Technological usability

The teachers were asked to give an overall mark for FLE3 on seven aspects. They had to rate these aspects on a six-point scale, ranging from (1) very bad to (6) very good.

On average, the teachers are positive about FLE3. It is easy to use ($M = 4.93$; SD = 0.70), and in general it is easy to go to the places you want to go to within FLE3 ($M = 4.40$; SD = 1.24). Screen design ($M = 4.60$; SD = 1.06) and information presentation ($M = 4.67$; SD = 0.72) are good, indicating that items are at the right place on the screen, and that the information is presented clearly. Overall, teachers think that FLE3 has a good aesthetic value (indicating beauty or elegance) ($M = 4.47$; SD = 1.36), and teachers think that from a student's point of view, FLE3 is attractive ($M = 4.73$; SD = 1.03). The overall functionality of FLE3 is good ($M = 4.67$; SD = 0.63). Only a few "negative" scores are given, three for the aesthetics, two for navigation, two for screen design, one for information presentation and one for the students' perspective.

In upper secondary education, teachers evaluate FLE3 less positively (on the average). Due to the small number of teachers, it cannot be said whether this difference between primary and secondary teachers is significant.

Teachers were also asked to rate the ease of use of various functionalities within FLE3. The rating of the answers is: (1) Difficult, (2) Not easy, not difficult, and (3) Easy.

According to these results, it can be concluded that the involved teachers think all functionalities of FLE3 are easy to use. Setting up a course ($M=2.93$; SD = 0.26), inviting people for a course or group ($M=2.73$; SD = 0.46) WebTop ($M=2.73$, SD = 0.46), creating folders, files, links and notes on the WebTop ($M=2.60$; SD = 0.51), management and organization of folders, files, links and notes ($M=2.60$; SD = 0.51), knowledge building area ($M=2.60$; SD = 0.51), thinking types ($M=2.60$; SD = 0.63), and attaching figures and links to knowledge building messages ($M=2.71$; SD = 0.47) have good scores. Only the Jamming functionality is difficult to use (on average: $M=1.40$; SD = 0.52). However, this can be explained by the fact that the teachers were not specifically introduced to Jamming, or how it could be applied, thus, only few of the teachers tried it. It can be stated that their opinions related to Jamming were based on first impression, not knowing even how the tool could be used.

4.3.2. Pedagogical effectiveness

The Finnish teachers were asked to rate the functionalities of FLE3 on its effectiveness for collaboration between students. They had to rate the usefulness on a three-point scale, ranging from (1) "little" to (3) "much". Table 4 shows the results.

It can be concluded that according to the participating teachers all functionalities are above average in their usefulness for collaboration. The score of the functionality Jamming is below average. This may be caused by the fact that teachers rate the technical usability of Jamming as not so good. However, as mentioned above, this can be explained by the fact that the teachers were not specifically introduced to Jamming, or how it could be applied. The management and organization of folders, files, links and notes also had scores just below the average. The best contributor to collaborative work of students is the knowledge building area, and the thinking types therein. Almost unanimously, the teachers claim that these are most useful for collaboration.

Table 4
Effectiveness for collaboration per functionality of FLE3

Functionality	Primary education			Lower secondary education			Upper secondary education			Total		
	M	*N*	SD	*M*	*N*	SD	*M*	*N*	SD	*M*	*N*	SD
Webtop	*2.33*	6	0.52	*2.50*	2	0.71	*2.25*	4	0.50	*2.33*	12	0.49
Creating folders, files, links and notes on the Webtop	*2.33*	6	0.52	*2.00*	3	1.00	*2.25*	4	0.50	*2.23*	13	0.60
Management and organization of folders, files, links and notes	*1.83*	6	0.41	*1.67*	3	0.58	*2.00*	3	0.00	*1.83*	12	0.39
Knowle dge building area	*3.00*	7	0.00	*3.00*	3	0.00	*3.00*	4	0.00	*3.00*	14	0.00
Thinking types	*2.71*	7	0.49	*2.67*	3	0.58	*2.75*	4	0.50	*2.71*	14	0.47
Attaching figures or links to KB messages	*2.57*	7	0.54	*2.33*	3	1.16	*2.75*	4	0.50	*2.57*	14	0.65
Jamming	*1.25*	4	0.50	*2.00*	2	0.00	*1.50*	2	0.71	*1.50*	8	0.54

Furthermore the (Finnish) teachers were asked to give their opinion on statements, related to the pedagogical effectiveness of FLE3. The scale used here is a five point Likert scale ranging from (1) "I fully disagree" to (5) "I fully agree".

On the average there is a reasonable agreement among the teachers on almost all statements of the questionnaire, indicating that FLE3 was easy to use for collaborative work. For example: the scores on the statements "While working in FLE3, the students understood how the process of inquiry goes on", "The students were evaluating together the inquiry process during the project", and "It was easy for the students to collaborate with other students via FLE3" were high or above average ($M = 4.14$; SD = 0.69, $M = 4.14$; SD = 1.07, respectively $M = 3.67$; SD = 0.82).

The scores on the statements "I guided the students to write research problems related to their topic of study to FLE3" ($M = 4.27$; SD = 0.80) and "I guided the students to make deepening questions to FLE3 during the process" ($M = 4.0$; SD = 0.76) indicate that the task for teachers to support and scaffold this process was easy as well.

5. Discussion

From the results, it is encouraging to observe that teachers rated the ITCOLE software fair (on average), even though they were new to it in both a technological and a pedagogical way. Collaboration between technical and pedagogical experts resulted in software that offers new possibilities to teachers that they seem to like and that are user friendly. Collaborative learning can be supported by computers in such a way that knowledge building becomes a real possibility.

A point of discussion is whether there is a relationship between the familiarity of teachers with theoretical frameworks such as progressive inquiry and knowledge building in general, and the user satisfaction of the CLE. If a teacher is familiar with social-constructivist approaches, this could influence his judgement on the used CLE (positively or negatively). For example: the Dutch teachers had few experiences with collaborative learning in general. Second, it is an open question whether there is a relationship between the familiarity of teachers with ICT in general (or even other virtual learning environments), and user satisfaction of the CLE. The teachers' judgement of the currently used CLE could be influenced – positively or negatively – by his or her experiences with another virtual learning environment (e.g. BlackBoard). Finally, an interesting question is whether the concept of collaborative learning of researchers and teachers match. A more qualitative analysis has to be done to study how teachers define "collaborative learning". Furthermore, a comparison could be made of the concepts of teachers and researchers.

6. Conclusions

In this study we focussed on the evaluation of the ITCOLE-software from the point of view of user friendliness and user satisfaction concerning the various functionalities (especially the pedagogical usability), as far as the involved teachers are concerned.

Most teachers claim that the environments are easy to use, and (after you had some training with it), it is easy to find your way in the environments. In some cases, teachers reacted more

negatively. This may partly be caused by slow Internet connections and partly by too little training before actually starting to work with the environment. In general, however, the teachers are positive. Overall the ratings for screen design, information presentation and aesthetics are high.

It is likely that teachers need training beforehand, both on the technical aspects of the environment, but especially in the pedagogical use – collaborative learning – of a CLE. For teachers, it is important that they have some (pedagogical) guidelines to get started.

Concerning the second research question "Are the involved teachers satisfied with the functionality provided by the system?" it can be said that both the users of FLE3 as Synergeia are satisfied with these tools. The overall functionality is rated as good, and the various functionalities individually are rated good as well. Some functionalities are rated as average (Jamming for FLE3; MapTool and instant messaging for Synergeia). For Synergeia, this is partly caused by general technical difficulties especially in the case of the MapTool, resulting in lower ratings in some testing sites.

Concerning the pedagogical usability, the teachers think that the combination of functionalities in the tools provides a good environment for collaboration. It can be concluded that all functionalities have added value for the CLEs.

Based on the experiences of the ITCOLE-project it becomes clear that it should be stimulated to develop CLEs, using pedagogical principles as starting point. Software developers and pedagogical researchers succeeded in the development of CLEs that where user friendly and pedagogical useful. Because of the interaction with end users they managed to design and development collaborative software systems, which maintain synchronous as well as asynchronous collaboration that can be integrated in a web-educational environment. Since this was one of the main challenges of the ITCOLE-project, it can be concluded that this European research and development project was successful. Nevertheless we mentioned two points of discussion that are related to the paradigm of collaborative learning, using ICT (see Section 6). If there is no match between the concepts of teachers and researchers on collaborative learning, the user satisfaction concerning the pedagogical usability could be questioned. In the introduction of Section 3 we mentioned that the design of a CLE is only partially a software design challenge. It is also a matter of designing appropriate pedagogical and epistemological infrastructures. These infrastructures could be important influential factors on the pedagogical usability of a CLE.

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