COLDEX,

Collaborative Learning and Distributed Experimentation

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Authors: Milrad, Marcelo; Björn, Marianne; Karlsson, Marine & Ulrich, Hoppe
Contact: marcelo.milrad@msi.vxu.se

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1 Introduction

The Collaborative Learning and Distributed Experimentation (COLDEX) project aims at developing and using new IT approaches and computational tools to foster scientific experimentation, modeling and simulation in distributed collaborative settings in an inter-cultural (European-Latin American) community of learners. The educational objectives of the project have been defined as follows:

- *Learner centered approach to design and evaluation of the technology and scenarios*
- *Active science discovery in mixed groups*
- *Stimulate creativity*
- *Enable cultural diversity*
- *Develop new methodologies for creating, processing and exploiting digital content*

There is a common denominator for the learning content to be addressed: the study of visual and other perceptual phenomena from both a scientific and an experiential perspective, i.e. by combining scientific and engineering methods with the subjective inter-personal communication of phenomena in the learning community. The scientific and engineering approaches will contain:

- *Generation and provision of source data*
- *Construction of realities*
- *Concrete modeling and design*
- *Abstract and conceptual modeling*

This deliverable is part of the COLDEX work package 2 (WP2 - 'Pedagogical Models and Scenarios'). The objective of this deliverable is to outline the learning requirements and design learning models, which will be used during the course of this project.

2 Theoretical foundations

During the last centuries a considerable number of pedagogues and educational practitioners (e.g. Comenius, Pestalozzi, Montessori and Dewey) have stressed the importance of visualisation and of hands-on experiences as vital components to the learning process (Bransford et.al, 1999). As a result of these efforts, several different pedagogical methods have been developed. Most of these methods are in many cases used in lower grades at elementary school. However, as the age of the students increase, the teaching methods and the learning processes tend to be more theoretical and abstract.

Emerging trends in education are moving towards learner-centered approaches where learning becomes an active process of discovery and participation based on self-motivation rather than on more passive acquaintance with facts and rules (Sfard, 1998). The ideas of collaboration and joint construction of knowledge have also found its way into the school system. However, in many cases this knowledge construction process does not involve teaching/learning in authentic scenarios or *real world* activities.

During the last century Jean Piaget conducted research on the development of human knowledge. The learning theory referred to as constructivism derives from his research. He asserts that the individual through action, in interplay with the environment, constructs knowledge. Fundamental to his theory, is the fact that knowledge cannot be transmitted it has to be constructed. The learner assimilates new knowledge or ideas and than changes his perspective to accommodate them (Piaget, 1969).

Several instructional methods are built on Piaget's ideas, e.g. learning by discovery; open-classroom learning; experiential learning; and inquiry learning (Koschman, 1996). Based on the ideas of constructivism, Seymour Papert and other researchers at MIT developed a theory for learning and educational strategy named constructionism (Ackermann, 1996).

Papert (1983) sees computers, or rather the activity of programming computers, as a construction material. He argues that computer programs are interesting artifacts for learning because they are executable (ibid). Constructionists stress affect, and argue that learners are likely to make new ideas when they are engaged in making an external artifact, which they can share and reflect upon. Personally meaningful activities and projects are most likely to engage learners intellectually. A constructionist-learning environment acknowledges that there is a multiple representation of knowledge and that there exists multiple learning styles among the learners (Kafai & Resnick, 1996).

Cognitive flexibility theory (Spiro et al., 1987) and social constructivism (Gargarian, 1996) are also learning theories related to constructivism. The Cognitive Flexibility Theory views learning as context dependent and that the learner has to participate actively in the educational activities. It advocates a need for bottom-up and case-based processing and top-down conceptual processing. One of its focuses is on increasing the learner's awareness of ineffective learning and the subject's complexity (Feltovich et al., 1996). Furthermore, the theory claims that there is a need to provide multiple representations (mental models) and varied examples to promote generalisation and abstraction processes, in order to promote understanding of the underlying complexity of the system under investigation. Learning should be supported with a variety of problems and cases, which is especially important in distributed learning environments. Computer software produced according to this theory encourages reflection of alternatives (ibid).

According to traditional constructivists, meaningful learning involves will, intention, action, consciousness and constructive practice including a cycle of reciprocal intention – action - reflection (Jonassen et al, 1999). The focus is on the individual's construction of meaning in a social and cultural context. To social constructivists, meaningful learning involves the social negotiation of meaning and joint construction of understanding by participants in an activity (Stahl, 2002). The focus here is on the group and on analysing interaction. Knowledge construction is an essentially social process (Koschmann, 1996).

The same view, as the one embraced by social constructivism is shared by the learning method we are suggesting to apply in the COLDEX project, namely Challenge-Based Learning (CBL). The main concepts in Challenge-Based Learning are inspired by ideas of social constructivism but also the method problem-based learning (PBL) as described below. These views stress curiosity and interest in real-world phenomena as motivational principles.

PBL emphasizes solving authentic problems in authentic contexts. It is an approach where students are given a problem, which contains all the complexities typically found in real world situations, and work collaboratively to develop a solution (Barrows, 1985). This approach was developed in the fifties for medical education, and has since been used in various subject areas such as business, law, education, architecture and engineering. The method provides students with an opportunity to develop skills in problem definition, problem solving, metalearning, and a deep understanding of the content domain (Spiro et al., 1988).

The CBL method advocated by COLDEX can be described as an extension to problem-based learning, but it contains also some components from the experiential, project-based and discovery-based learning perspectives. Project-based and problem-based activities are usually focused on a driving question or problem (Jonassen et al, 1999). In CBL the question or the problem is combined with a challenge.

The challenge, in a challenge-based learning activity, is initiated either by the COLDEX project, a teacher or a student group. The assignments or "challenges" to be solved might include ways to develop, design and implement solutions for problems related to scientific phenomena. A meaningful learning activity consistent with CBL is to present learners with a challenge scenario and to ask them to think about a number of possible solutions using a variety of interactive tools. Such an activity serves to center thinking around meaningful problems and is typically effective in facilitating small group collaboration. Table 1 illustrates how CBL differs from some of the learning methods.

	Discovery-based	**Problem-based**	**Experiential learning**	**Challenge-based**
Cognitive focus	Knowledge inquiry	Knowledge construction	To grasp and transform experience	Knowledge interpretation, inquiry and construction
Role of student	Detective, picking up clues	Participant, searching	Active participant, choosing	Active constructor/ designer
Role of teacher	As mystery writer	Coach	Facilitator	Coach, co-experimenter and designer

Tabell 1 Challenge-based learning and other learning methods.

An important part in COLDEX is the Information and Communication Technology (ICT) support for the communities. In the next chapter, we will specify different aspects of the proposed activities and possible technological support.

3 Educational Activities, Tools and Technology

> *"From the time of Galileo until fairly recently, there were two complementary ways of doing science: experiment and theory. Now there is a third way. Computer modeling…"*
>
> (Feurzeig & Roberts, 1999)

3.1 Designing for Learning

Current and emerging technological advances in information and communication technology make it possible to develop interactive learning environments to support new ways of learning. A technology-supported learning environment can visualize concepts that are difficult to understand. The students can work with software tools for visualization and modeling that are similar to the software used outside the school. This kind of learning environment may increase their understanding and the transfer of what they have learned from the school context to a non-school setting (Bransford et al, 1999).

Interactive learning environments play an increasing role in teaching and learning. The interactivity facilitates the creation of an environment that supports learning by doing, gives feedback and helps the students to cultivate their understanding and to build knowledge (Bransford et al, 1999). Bourdeau et al., (2000) point out that to enable students to create their own learning community, it is important to create an environment where the processes of coordination, communication and collaboration are transparent.

Two interesting examples of interactive learning environments (ILE) for science learning are the RiverMUD developed the ScienceWare project at the University of Michigan, and CoVis, The Learning Through Collaborative Visualization Project (Jonassen et al, 1999). Both environments combine project-based science and contain support for conversation, collaboration, and modeling, using cognitive and decision-making tools. These ILEs are, according to Jonassen et al (1999), good models of technology-supported learning environment for engaging contextualized, active, intentional, constructive, complex, collaborative, conversational, and reflective meaning making.

New technologies, which are used in these learning environments, provide new possibilities for learning and collaboration. Thus, it is important to remember that the technologies per se do not guarantee effective learning. It is even possible that inappropriate use may hinder learning (Bransford et al, 1999). To avoid improper use, the tools and the technologies should be part of a consistent educational approach and should offer supporting structures or scaffolding for thinking and activities (ibid.).

COLDEX suggests that the design of the interactive environments for challenge-based, collaborative learning and distributed experimentation should be guided by:

- *Authentic activities:* presenting authentic tasks that conceptualize rather then abstract information and provide real-world, case-based contexts, rather than pre-determined instructional sequences. Learning activities must be anchored in real uses, or it is likely that the result will be knowledge that remains inert.
- *Construction:* learners should be constructing artifacts and sharing them with their community.
- *Collaboration:* to support collaborative construction of knowledge through social negotiation, as opposed to competition among learners for recognition.
- *Reflection:* fostering reflective practice.
- *Situating the context:* enable context and content dependent knowledge construction.
- *Multi-modal interaction:* providing multiple representations of reality, representing the natural complexity of the real world.

It is also important to be *Learner-centered:* to take into consideration learner aspects, e.g. cultural practices and prior experiences and understandings, and *Knowledge-centered:* to help students become knowledgeable, and focusing on helping students in their knowledge acquisition.

The different learning activities which will be designed upon this framework requires learners to identify research questions and variables, set hypotheses, build and construct experiments, test results, analyze observations and then refine hypotheses and casual variables accordingly.

Figure 1 describes how these learning activities are interconnected following a specific workflow. This model has been inspired by Kolb's (1984) learning cycle but expanded to encircle the whole learning environment including collaborative aspects. Within this model, we refer to the learning environment as the combination of people, technology and educational activities.

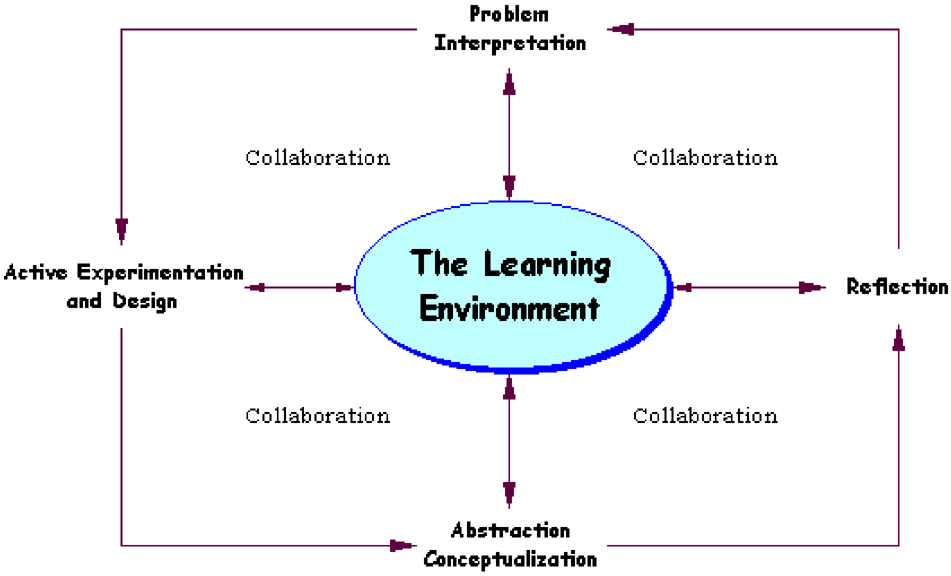

Figure 1. The learning environment with a collaborative learning cycle, based on Kolb's learning cycle.

Land and Hannafin (1996) point out that researchers and designers need to identify frameworks for analyzing, designing, and implementing interactive learning environments that embody and align particular foundations, assumptions and practices. There is a need for learning activities that stimulate an interest for understanding complex phenomena, challenge current understandings and facilitate experience sharing between learners.

Within the COLDEX project we are putting special efforts in exploring the integration of physical and computational media for the design of interactive learning environments to support learning about complex scientific phenomena. This effort involves the design of interactive learning environments to integrate systems supporting alternative ways of interaction to mediate social aspects of learning, knowledge construction, reflection and design. These interaction activities integrate the use of computationally augmented physical objects – to support and encourage face-to-face interaction among learners, with virtual objects – to provide computational support for the model underlying the simulation.

What should be included in a COLDEX framework? Spector (2001) identified eleven elements that are worth to reason about. The framework should:

- *Provide support for the collaborative construction of knowledge objects, for the collaboration construction and analysis of problem solutions;*
- *Provide tools to support negotiation of alternatives;*
- *Provide both public and private feedback support mechanisms;*
- *Provide mechanisms to share and exchange information, objects, views, etc.;*
- *Facilitate a meaningful division of labor;*
- *Support joint, online thinking, commentary, etc.;*
- *Include meaningful learning scenarios;*
- *Design authentic problems and legitimate cases as the basis for learning activities;*
- *Take into account the entire learning environment;*
- *Support mediation among all the participants;*
- *Foster a sense of collaborative learning community.*

The students should be provided with support or scaffolding in the beginning of the process. The learning environment will include the setting of experiments, the provision of 3D virtual scenarios, and artifacts that support other types of perceptual experience (e.g., tactile experience). A use of "mixed reality" technologies will allow for a smooth transition between the physical and the digital worlds. There will be a notion of concrete modeling and design and use of concrete representations to model and simulate the phenomena to be studied. These range from 3D models that include sound and tactile I/O to physical models with IT components (e.g. Lego Mindstorms). The idea is not to invent new technologies but to adopt existing state-of-art techniques to educational needs. Figure 2 illustrates some of these concepts.

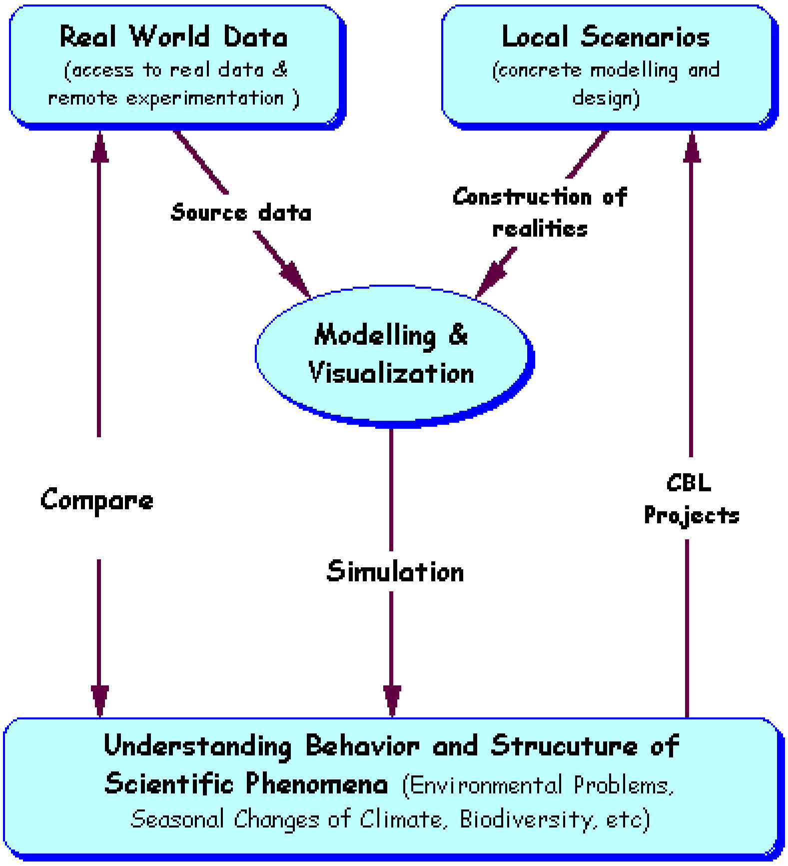

Figure 2. Challenge-based learning activites.

3.2 Learning Toolkits

In order to achieve the learning objectives and to conduct the learning activities we have described above, we will provide teachers and students with a so-called "Digital Experimentation Toolkit" or DExTs.

In addition to real physical objects (e.g. fuel cell kit, a hydroponics plant growth system, a weather station, etc), DExTs will include experimental instructions, scientific background information, modeling and simulations tools, access to real scientific data, and the formulation of initial challenges. The main idea behind DExTs is to provide learners and teachers with tools to support open-ended learning activities that stimulates them to identify and solve a challenge according to the educational premises of CBL.

There will be interactive tools for modelling and simulation where the learner can generate and try out hypotheses, and show his/her experimentation and results and to share it with others. In order to support these processes there is also a need for interactive spaces for the "reflective practitioner" (Schön, 1983), and tools for construction and design as a learning environment. As already mentioned in section 1, COLDEX activities are developed based on content related to complex scientific phenomena. In table 2, we are suggesting a number of scientific problems, which are associated with a particular DeXT.

	Modelling/ simulation	Distributed experiment.	Can be one-time experiment.	Can be part of long term project
Astronomy I (telescope)		x	x	x
Astronomy II (Lego Mindstorm)			x	
Earthquakes	x	x	x	x
Biosphere	x			x
Water rocket	x		x	
Navigation without sight	x			

Tabell 2. Suggestions on DexTs.

DExT's can be considered as tools for modeling/simulation and experimentation. The modeling tool is used when the students make a view about their thoughts early in a project, some kind of previous knowledge statement, or when the students are going to design something later on. Different simulation tools are needed for students testing estimated values and outcomes concerning different influences of events.

The experimentation tools are a prerequisite for the students to construct, visualize and confirm their thoughts in the learning progress. Essential for the toolkits is to get access to modelling and collaboration tools, and to a common repository. This will be done through Internet. A small number of remote sites will be established which generate data. Among these will be an observatory with a high quality telescope and a seismic measurement station in Chile. Technological challenges lie in the ease of use in accessing these data and in communicating the learners' requests and specifications to the remote sites. The stress is put on re-usable components and protocols that are not only tailored to the specific case.

We use tools as a *help (or mind tools)* to be able to do things. Although, the tool fulfills an important role for the teacher or the learner, the most important aspect is not the tool per se, rather the view of the tools as *artifacts* to be used for supporting the *creation of knowledge*. It should be noticed that this knowledge construction process it could be done in an individual or collaborative fashion. The tool is supposed to be an instrument to be used in order to reach understanding and development, preferably with an intuitive interface.

The ideas presented above are consistent with the concept of *collaborative mind tools*, as suggested by Hope et al. (2002). In a recent paper, they present an integration approach by providing "computational objects to think with" in a collaborative, distributed computing framework. Figure 3 makes an attempt to illustrate the combination of collaboration, communication and mindtools. This particular aspect is of great importance when it comes to educational activities and technology design in the COLDEX project.

Fig 3. Collaborative Mind Tools

A toolkit also consists of a collection of experiences coming from others community members, while this material is presented and stored in one place. DExT's, as we see them, includes

- *A formulation of an initial challenge issue with essential scientific background information and suggestions where to find more.*
- *Experimental instructions*

- *Modelling and experimentation tools*
- *Collaboration tools*

These toolkits should provide innovative use of interactive media to enrich the curricula. Teachers should easily integrate and make available these new resources. No teacher has time to spend on courses or time-consuming studies for “learning” to use our toolkit. It has to be self-describing and trouble-free. According to Barowy and Roberts (1999) an engineering model of experimentation can be to manipulate a model to produce a certain wanted outcome, and a scientific model of experimentation can be to try to achieve understanding by using the strategy of testing one control variable at a time.

Many of the existing approaches to supporting learning in science and engineering by using information and communication technologies fall short in several respects:

a) They generally do not take into consideration the global perspective of the phenomena being analyzed. This means, these tools serve for an individual use or at most for a relatively small (culturally homogeneous) group.
b) When applied to real educational situations, most efforts have been of short-term nature. This may be suitable for some domains (e.g. specific simulation experiments) but to really contribute to the aim of supporting science education a longer-term effort and more coverage of the curriculum is desirable.

Many efforts claim to include virtual experimentation as the core of the student’s activities. Usually, this excludes the “handcrafting” in the physical preparation of experiments on the part of the learner, which is one of the most important experiences that students can get from laboratories.

Realistically seen, curricula are typically organized in such a way that theory is not discovered in the laboratory but taught before. Thus, laboratory work can at best be about connecting theory to practice. Accepting these premises implies that hands-on experimentation should not be given up if it is easy to provide. We suggest concentrating on such virtual scenarios in which hands-on experience is not easily accessible. In this perspective, we agree with Spector (2001), when he claims ”…it is the design of a learning environment and not simply the use of technology that plays a key role in facilitating learning.”,

Every learner has his or her own way to learn and needs different kinds of support. To have opportunities to use “multi-modal interaction” is one way to solve the problem. It could be as smooth transitions between different types of model representations (Physical-virtual/3D-abstract). Another way to support this is making tools that are formable for the user. It could be freedom in ways to organize or handle things in the interface, to have options and settings to make own choices. Of cause this holds for...more advanced technology to a more advanced user.

There will be an advantage for the system using those functions mentioned above and additionally benefit if we can leave some choices to the teachers. Because they stands closer to the students than we do and related to that can do even better choices. The teachers ought to easily integrate and make available new resources (real or virtual experiments, documentations …as well as multimedia material). We look at teachers as creators of interactive materials that stimulate constructive and intellectually challenging activities on the part of the students.

At the end, the student should have several options to choose among, depending on age and knowledge level. We have to consider young adults who should be supported in making their own choices within the spectrum of learning offers. These tools are supposed to go beyond uniform computers as such towards mobile non-standard input devices and tangible interfaces. The ”just-in-time perspective”, instructional delivery, in which information and training are provided to learners at the appropriate moment and within a relevant context.”

To encourage distributed experimentation is important in COLDEX because that is one of the points with the whole project. For this we need communication in many different ways between members depending on what experimentations we are going to choose at the different universities.

One of COLDEX cornerstones is that learners should work with real data as close to the real world as possible. COLDEX propose to create and maintain large learner communities around complex experimental phenomena rather than focusing on small highly controlled laboratory situations. We want students to work as far as possible with authentic activities. Thus, students should for instance, conduct “field trips” to go collect data and experiences, or even will play some learning games, taking in this way an active part in the knowledge construction process (Gay, 2002; Colella, 2000).

4 Communities

In the COLDEX- project, the formation of learning communities is stressed. A framework will be developed which provides tools and methods for collaborative science learning that includes experimentation and modeling in local and distributed scenarios. The framework will facilitate collaboration, sharing of knowledge and best practices between communities, both locally and globally. A community can be defined as a social organization of people who share goals, values and knowledge (Jonassen et al., 1999). According to this definition, students in a classroom are a community only when they share common interests and work together towards a common goal.

It is important to remember that a technology-enhanced framework alone will not create collaboration and community building. It has been demonstrated that non-technical factors influence if people will use the technology and if they will collaborate (Bransford et al., 1999; Brazelton & Gorry, 2003). According to Bransford et al. (1999), three main factors should be considered while trying to design successful network-based communities. These three factors are described below:

- *An emphasis on group rather than on one-to-one communication,*
- *Clear goals or tasks*
- *Explicit efforts to facilitate group interaction and create new social norms.*

Salomon (1992) argues that interdepence between the learners is essential for the success of collaborative learning. Interdependece effects the division of labour, roles; the necessity to share; and the need for joint thinking. In a recent research project Brazelton & Gorry (2003) found out that face-to-face contact plays an important role in the beginning of the development of an electronic community. When community members have developed a personal relationship, it can be enough to communicate through the technology (Brazelton & Gorry, 2003).

One of the main crucial factors that is responsible for the difficulties with building collaborative educational scenarios around computer-mediated communication is *context*. Computer-mediated communication can hardly capture the full variety of non-verbal signals and situational references. But this is not even the biggest problem: context stems from shared history, from shared external environments (e.g., on a campus), and from shared daily routines (Nardi, 1996). All this is important in collaborative learning but hard to transmit through computer networks between humans who do not have regular face-to-face contact. So, when we say that the creation of global learning communities is a central issue for COLDEX, we have to consider the context problem. There are two consequences: (1) Build communities bottom-up, starting with local, usually face-to-face, communities such as school classes or study groups and let these establish contacts with other communities; (2) take subjective experience seriously (and not only scientific understanding).

The COLDEX project will build communities bottom-up, starting with local, usually face-to-face, communities such as school classes or study groups and let these establish contacts with other communities. A rich potential of human resources will be taken into account (teachers, tutors, peer interaction). Collaboration and networked interaction will arise from basic groups, using both synchronous and asynchronous collaboration techniques. We want students to discuss and share their results and subjective experience aimed at fostering collaborative knowledge building. Synchronous collaboration tools should contribute to forming a "group memory" which must also be available in asynchronous mode. Conversely, the use of archives and repositories should also be tightly integrated with synchronous activities. A consideration here is how to store synchronous activities in a way that they can be searchable and easily to retrieve (Brazelton & Gorry, 2003).

Science and technology may be seen as neutral to cultural backgrounds, as long as certain material resources for experimentation and modeling are given. However, for learning and experiencing scientific phenomena, we strongly believe that cultural, historical and experiential difference may play an important role. The variety of scientific phenomena we have chosen to study, have to do with perception and environmental conditions. In a number of cases, such as seismic activities, environmental problems or astronomic observations, understanding of these phenomena will be quite different depending of countries where the phenomena is under investigation. For instance, Swedish kids will have a complete different conception of an earthquake comparing with Chilean children.

After encouraging the building local communities, our attempt is to let these communities to establish contacts and share experiences with other peers. There should be support for communication of subjective and culturally/geographically dependent views of natural and experimental phenomena (see figure 4). The students are given a chance to take a global perspective of the phenomena of interest. Thus, access to these common data, will also be a source of learning from each other, in a multicultural community and it will hopefully foster inter-cultural understanding. Within the framework of COLDEX, we have to make provision of adequate tools for supporting and communicating rich experiences as well as for maintaining communities archives and "memories".

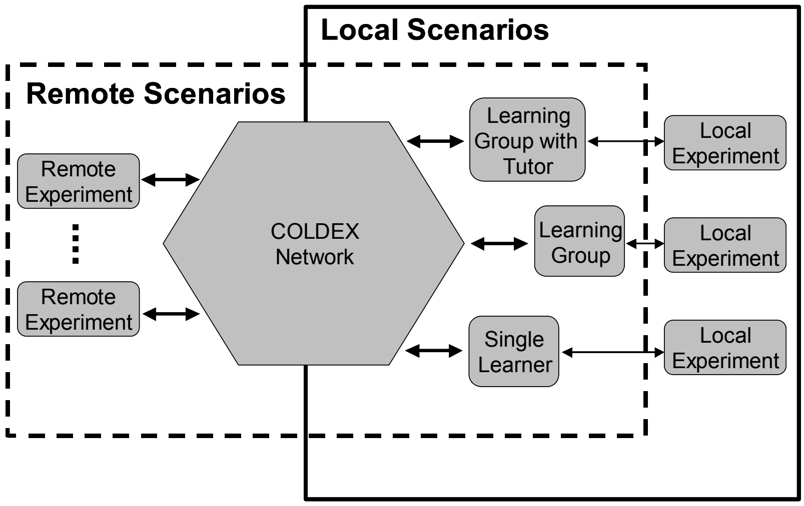

Figure 4. Remote and local scenarios. From Communities of Practice to Networks of Practice

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