Collaborative Learning and Research Training: Towards a Doctoral Training Environment

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Abstract

Doctoral training has not been studied in depth as a learning situation, and no learning environment has been designed to specifically support actors involved in the training of future researchers. The research literature on doctoral education indicates that the knowledge about doctoral training needs to be made explicit and formalized. We claim that several problems brought up in the literature on PhD Training could be reduced or solved by a doctoral training environment designed on the basis of a cognitive analysis.

Doctoral training in the sciences consists essentially of research training through immersion in scientific communities and activities. Collaborative learning is built in authentic research situations, where doctoral students discover collaborative research. The model of a 'Collaboratory' provides the foundations for the practice of collaborative research. Future researchers are expected to be competent in practicing 'E-science' and knowledgeable about distributed research with remote access to shared instruments. The ability to practice 'Co-experimentation' is part of the research skills.

An authoring environment has been prototyped as well as an instantiation of a PhD program in the field of Cognitive Informatics One Use Case consists of two or three research distributed teams sharing observations and discussions, a research training situation involving immersion and collaborative learning. A series of tests and co-experimentations involving Inquiry Learning Environments as a topic of study in the field of Technology-Enhanced Learning was conducted. An international collaboration happened through Kaleidoscope and the co-experimentations were made possible by an optical network infrastructure providing high quality interactions in terms of sharing and telepresence.

1. Introduction

What is doctoral training made of? This learning situation has not been studied thoroughly, nor have the problems of learning environments to support this situation in the field of Technology-Enhanced Learning (TEL).

We claim that immersion in scientific communities and participating in collaborative learning activities are two essentials of doctoral education. A research training environment should support these activities through interactions among several actors using top-level instrumentation. An analysis of actors, activities, resources, and competencies has been conducted in order to make explicit and to model the dynamics of research training through immersion in scientific communities and participating in collaborative learning activities. An authoring environment has been prototyped to support such activities inside specific PhD programs. One Use Case consists of two or three research distributed teams sharing observations and discussions, a research training situation involving immersion and collaborative learning. A series of tests and co-experimentations involving Inquiry Learning Environments as a topic of study in the field of Technology-Enhanced Learning was conducted. An international collaboration happened through Kaleidoscope and the co-experimentations were made possible by an optical network infrastructure providing high quality interactions in terms of sharing and telepresence.

This paper describes the problem tackled, the methodology that was selected, and the results obtained.

2. The problem

In their "Recommendations from National Studies on Doctoral Education", Nyquist and Wulff [9] reviewed recent national studies on doctoral education in the US: "three themes that strongly emerge are:

Current graduate education does not adequately match the needs and demands of the changing academy and broader society; there is a lack of systematic, developmentally appropriate supervision for many who are seeking careers that require or benefit from the attainment of a Ph.D.; and there exists a growing concern about the high level of attrition among doctoral students". Problems brought up in the literature on doctoral training [1], [2], [3], [4], [5] include the lack of definition of expected competencies, the inadequation between program requirements and available research training activities.

We claim that the main reason for those problems is the lack of explicit knowledge about the nature and the characteristics of a doctoral training in general and of specific doctoral programs in particular. We believe that most programs share many common elements although they have different cultures, depending on the disciplines, countries and institutions.

The first issues triggered in this project deal with the process of making explicit and formalizing this knowledge which is required to design a DTE on a scientific basis.

Second, a doctoral training environment should be aware of current evolution in the scientific world, and be ready to support what is now called e-Science. The term was coined by John Taylor who stated: 'e-Science is about global collaboration in key areas of science and the next generation of infrastructure that will enable it' [6]. In the United Kingdom, e-Science projects span a range of disciplines from particle physics and astronomy to engineering and healthcare, and include international collaborative activities. Access to top-level instrumentation is a key to conducting e-Science, and optical networks are pivotal to this access.

In the spirit of a 'Collaboratory', the DTE needs to be equipped with a network infrastructure that can support immersion in a community and access to scientific instrumentation.

3. Methodology

First, a general characterization was carried out to draw the mandatory DTE orientations for the training of future generations of scientists, to prepare them for what is called 'E-science' [6]. An inspiring model, the Collaboratory [7], was selected and provided the foundations for practicing collaborative research. Two features were identified as essential for doctoral training: immersion in scientific activities (such as co-experimentation) and in communities, and access to top-level instrumentation based on performance, safety, and privacy.

Then, a systematic analysis of processes, actors and resources was conducted, a fundamental step in designing a learning environment. Defining research competencies proved to be quite an ordeal. A substantial challenge concerns the support to developing research competencies, beginning with their explicitness.

Concerned with reusability, the team emphasized the fact that common grounds should be found for doctoral processes, and that generic learning objects or resources should be shareable as is recommended and now supported by recent technologies [8].

As a result, the team's objectives was to design an authoring system that allows DTE designers to instantiate their own DTE which reflects their own views, to pilot and instantiate a DTE in order to test and validate the ideas with authentic users placed in specific situations.

How can a doctoral training environment be sufficiently sophisticated to support the development of high-level skills through interaction among several actors using top-level instrumentation? An analysis of actors, activities, resources, and competencies has been conducted in order to make explicit and to model the dynamics of research training, and to obtain a design rationale.

4. Making Knowledge about PhD Training Explicit

Can the knowledge about PhD Training be made explicit? If so, why should this be? Traditionally, PhD supervisors resist the idea that it is possible and potentially beneficial to students for reasons such as: training methods are too peculiar, fuzzy, and interpersonal; it is better for students to discover by themselves, to make up their own mind and to pave their own way; it is the prerogative of each supervisor to say what they want to their students, etc.

Other reasons for this resistance could be the belief that doctoral training is so intertwined with research, and research is so competitive, that this knowledge ought to remain secret; or that doctoral education consists of initiating rather than training, and should therefore be transmitted 'by word of mouth'.

On the other hand, students often indicate they wish they had known in advance (and all along the process) what they should expect and what is expected from them [9], [10]. They also regret lacking a priori knowledge about the doctoral training process: "Had I only known….” Such feelings might contribute to the high dropout rates.

Such a situation appears paradoxical for researchers in our field. Specializing in computer and cognitive sciences, and experienced in principled design of learning environments, a team such as ours, could not remain indifferent to this challenge.

Below is a short description of our analysis of the doctoral training process, and of research training competencies.

The next section introduces the building and testing of a ligthpath network, and the design of an e-controlled experimental laboratory. This is followed by a short description of co-experimentations, showing the inclusion of an international dimension in a private scientific network.

4.1. The Doctoral Training Process

From the very beginning, the team tackled the analysis of the main processes and sub-processes of doctoral training, as well as the actors and resources associated with them [11]. It soon became clear that it was impossible to strictly draw the line between processes common to most PhD programs and those which are specific to a discipline or an institution. A reasonable approximation was made: the doctoral training process can be split up into five main sub-processes. These sub-processes are: registration, academic program, student support, scientific immersion, student life, and career preparation (Fig.1). All of these sub-processes imply the participation of at least two of the following actors: student (enrolled in a program), professor, research staff, manager, and public (none of the above). These actors interact with each other and with the environment. A single user (human being) can play the roles of one or several actors.

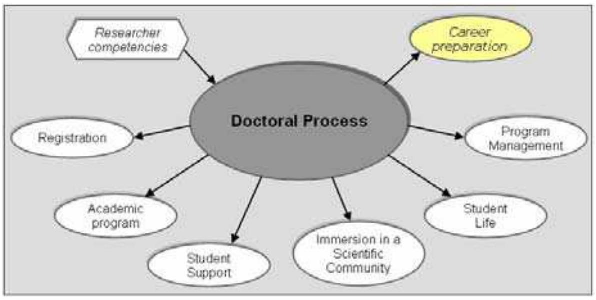

Fig. 1. The doctoral process

All actors cooperate in the pursuit of the goal of the doctoral training process: to support the development of research training competencies. Therefore, the whole process should be governed by these competencies and the need to support students developing their competencies. The PhD diploma is considered one expression of the recognition of the successful completion of the doctoral training process.

4.2. Research Training Competencies

Similarly to the analysis of the doctoral process, it was impossible to strictly distinguish between competencies common to most PhD programs from those which are specific to a discipline or an institution [12]. Another challenge consisted of reconciling competencies with skills and also sometimes with objectives, since these terms do not always share the same semantics, both in the literature [13], and in the actual everyday life of a PhD program [14]. The notion of competency itself is currently under scrutiny in order to orient the future design of an agent capable to diagnose these competencies. The list of skills proposed by the British Research Councils and the Arts and Humanities Research Board [15] was selected as a reasonable common basis for most PhD programs. These ‘Skills training requirements for research students’ are organized into five categories:

A) ‘Research skills and techniques - to be able to demonstrate skills such as: The ability to recognize and validate problems; Original, independent and critical thinking…

B) Research Environment - to be able to: show a broad understanding of the context, at the national and international level; understand the processes for funding and evaluation of research…

C) Research Management - to be able to: apply effective project management; design and execute systems for the acquisition and collation of information…

D) Personal Effectiveness - to be creative, innovative and original; demonstrate self-discipline…

E) Communication Skills – to write clearly and in a style appropriate to purpose, e.g. progress reports, published documents, thesis; to construct coherent arguments …

F) Networking and Teamworking - to develop and maintain co-operative networks and working relationships …

G) Career Management - to appreciate the need for and show commitment to continued professional development; to take ownership for and manage one's career progression…’

5. Results

This section introduces the results obtained sofar: a prototype of a doctoral training environment with graph-based navigation and support to emergent activities within communities, the building and testing of a network infrastructure, the access to an e-controlled research laboratory, and the conduct of co-experimentations at the international level.

5. 1. Prototype of a Doctoral Training Environment

After extracting the design rationale, a prototype of a Doctoral Training Environment (DTE) was developed with its processes, actors, and resources. This section introduces the DTE Architecture and the implementation of the DTE authoring tool, called DTE-Author.

At the heart of the DTE is a set of links between conceptual entities: actors and their roles, activities and actions, competencies and resources. These links form the conceptual architecture [16], as illustrated in Fig. 2.

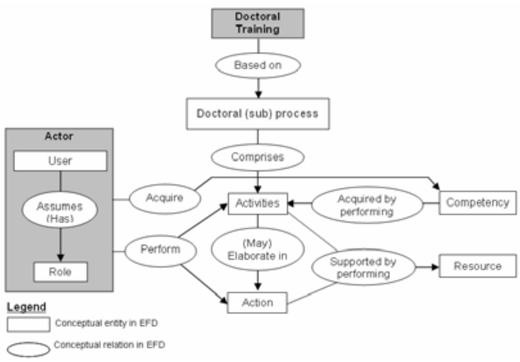

Fig. 2. The conceptual architecture of the DTE

This conceptual architecture provides the foundation for the functional architecture (Fig.3) and consequently the development of the DTE authoring tool.

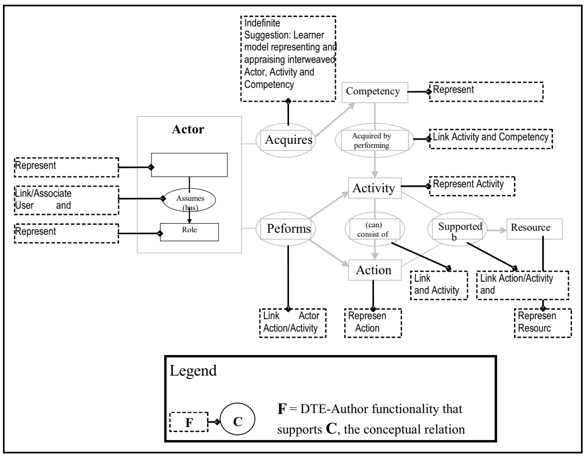

Fig. 3. The Functional Architecture of the DTE

This implementation is explained in video recordings for the users' benefit, to support them when designing an instantiation, i.e. a DTE-X.

The DTE Authoring Tool allows users to design and generate Doctoral Training Environments (DTE), hence its name: DTE-Author. It was built upon CONCEPT@, Télé-université's authoring environment, in connection with PALOMA, its learning objects repository. The rationale underlying the DTE-Author results from the cognitive analysis and includes three main features: 1) a doctoral process composed of six sub-processes: registration, program support, program activities, scientific immersion, student life and career preparation, 2) a competency model for future researchers, 3) interactions amongst various actors.

The goal of the DTE-Author is to allow users (authors) to create a process-based multi-actor environment specific to a given program (hereafter named DTE-X) that supports the development of competencies needed by future researchers. Thus, the authoring tool proposes the following method to design a DTE-X: 1) clarify each basic process in terms of doctoral activities, 2) specify each doctoral activity by linking it with the acquisition of a research competency, 3) assign specific resources and actors to each doctoral activity. The activity is considered as a set of actions, each action being carried out by an actor and supported by a resource.

The "author" is the only actor who uses the DTE-Author to design a DTE-X. The DTE design process is composed of four steps: identify the DTE-X, develop, configure, and generate the DTE-X. Each step is briefly described below:

1. Identify the DTE-X. This first step includes the following: name, select an abbreviation, and save. The

system launches the six doctoral sub-processes and its corresponding activities, illustrated by files in a tree diagram whose specific nodes represent learning activities.

2. Developing the DTE-X. The second step consists in defining its structure in detail: add/modify a sub-process, delete a doctoral sub-process, add/modify an activity within a process, delete an activity within a process.

3. Configuring the DTE-X. The third step consists in configuring the activities:

- Associate a research competency to an activity by selecting from a set of competencies or by adding another one
- Associate a resource to an activity. The DTE-Author includes four types of resources: application resources, NetNuke resources, generic resources and default resources. Application Resources consist of software which can be used for an activity. DNN Resources are resources used to design a DNN: newsgroups, e-filing, Weblist, etc. Generic Resources are documents: MS Office files, HTML, URL, pictures, videos, etc. For certain activities, the DTE-Author offers default resources that can belong to any of the three previous categories. Designers can view and select those considered most appropriate. Activity and resources deemed less relevant can be replaced by resources considered more appropriate. Designers can add their own applications.
- Associate an action to a specific activity if needed. The DTE-Author provides designers with two possibilities for each activity: select an action amongst a set of actions proposed for each activity; add a new action.
- Associate a resource with each action. To do so, authors consult ors send a request to a Learning Objects Repository. Furthermore, they can select or add a new resource of their choice.
- Associate an actor with each resource involved in the activity. In the framework of this action, users' rights must be taken into consideration.

At this point, once all links have been created as illustrated in Fig 4, the instance, i.e. a DTE-X, can be generated.

Fig. 4. Configuring the DTE-X

4. Generating the DTE-X. The fourth and last step consists of generating a Website or portal which supports this learning environment:

- Configure a generic/permanent Website menu that provides generic services (a CONCEPT@ functionality): select a template, test, and generate the DTE-X.

As a result, the user-author obtains a learning environment organized as a tree structure. However, she can also select an alternate mode to visualize this structure and navigate: the graph-based mode.

5.2. Graph-Based Navigation

The doctoral process can be viewed as an institutional accreditation process: institutional steps are well defined with rules for registration, academic program, thesis defense, etc. However, it is also a research and development process, where creativity, innovation and adaptation for individual research take an important part. For such areas, a more open and emergent coordination framework must be drawn. Although it is less organized and uniform, some kind of structure and support can be provided to coordinate activities amongst the academic participants, for example for a series of seminars, or to formalize emergent coordination between professors and their students, to ensure follow up, support and progress.

For those more open and emergent structures of activities, we decided to integrate Explor@Graph. This flexible navigation environment is based on conceptual maps, where different structures of activities, resources, concepts or others entities can be freely described and navigated according to users' rights. Explor@Graph first presents a metaphor appropriate for the DTE: space exploration, brain neurons, connection amongst elements. Second, the system respects ergonomic principles for improved usability, offering high visibility, flexible navigation, progress feedback, collaborative features and adaptive interfaces to support progression. For example, it is possible to introduce dynamic help features, deadline reminders or simply remind users of the conference of the day.

Explor@Graph was developed from a standalone application in VB to a Web-based VB.Net version, called Explora@GraphNet. It was then linked to the DTE. Therefore, it offers graphic interfaces as an alternate browser within the DTE, exporting the process and sub-process structures, and allowing the creation of other more flexible structures with the Explor@Graph Editor. As a result, the system can display the same structures either as a tree diagram or a graph, and can launch the same resources in either mode. In order to integrate the processes defined in one mode or the other, we developed a framework of ontologically defined data exchange using a SESAME database. In this generic solution, (sub)process structures are defined as OWL structures, and an exportation module is specified from the DTE and from Explor@Graph to communicate process structures to the SESAME database. For flexible navigation within the DTE, Explora@GraphNet displays such structures (Fig.5).

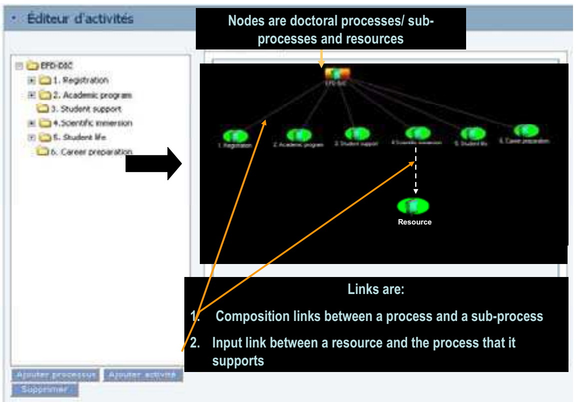

Fig. 5. Graph-based Navigation with Explora@GraphNet

This generic system could be used to communicate with other applications developed in the context of LORNET, such as resource or participant structures.

5.3. Emergent activities within communities

The need to 'leave room for emergence' was clearly expressed by the focus groups organized by the pilot team. The pilot study consists of instantiating a DTE-X for the PhD Program in Cognitive Informatics at TELUQ-UQAM, hereafter called DCI. As a result of two focus groups, one with professors and the other with students, the team decided to complement the DTE activity structure and to innovate by designing for emergent activities within communities – scientific community, program community, student community, etc. A conceptual and functional architecture is currently being designed to achieve this goal.

Our main challenge in designing DCI's DTE is to materialize our conceptualisation of doctoral studies in terms of human communities. In our view, immersion into a scientific community is a key factor for a doctoral program because it permits doctoral students to get involved in authentic research situations allowing them to develop their research competencies and to get acquainted with the collaboration process within such communities. Collaboration among researchers at local, regional or international levels is fundamental to improve research productivity. Getting exposed to the activity of a research community is crucial for the training of doctoral students. Collaboration constitutes the locus for immersion into the scientific community. Since immersion is an emergent process that cannot be systematically planned, we had to find a way to induce and support it. Immersion in a scientific community banks on communication, sharing and networking and on people's adhesion; it calls for influence, conviction and autonomy. Three main principles have been adopted to guide the design of the DCI's DTE in terms of immersion in a scientific community. Firstly, doctoral processes and research competencies associated with them have to be made explicit to the students in order for them to be able to manage their own competency development. Secondly, the various resources that could support competency acquisition and immersion processes should be easy to access and to manage. Thirdly, communication and information flow should be highly transparent for students as well as for all members of the DIC program using the DCI's DTE. These three principles are implemented in the DCI's DTE mainly through the design of the interfaces, the creation of a personalized administration space, as well as by letting the members of the DCI's community free to use their own tools (email, chat, blog, etc.), and by the use of RSS feed. Using an RSS aggregator allows for the visualization and handling of consolidated information. It is an effective way to support information flow and the sharing of information. The home page is personalized and divided in three main sections. In the upper part, a TreeMap represents the doctoral processes, and indicates to students their own progress. In the lower part, the students access the various RSS feeds referenced and an interactive calendar that gives access to the feeds' history. There are two types of feeds: the ones created and selected by students and the mandatory ones given by the DCI's DTE manager (for example, News from the program, Changes in the program site, etc.). The heading, common to all pages of the environment, gives users access to their own administration space as well as to their favorite URLs and other RSS feeds. This home page has been designed to be easily integrated by the user in an external site. Giving the users the possibility to implement this page on their own site should stimulate their participation. Another section of the DCI's DTE gives access to a TreeMap representing the research competencies. It allows the students to manage their progress throughout the process of acquiring competencies.

The personal administration space allows users to manage their personal email addresses and syndication channels (RSS feeds), and to add their favorite RSS feeds and references. This space also identifies the resources and the information the user wants to access, and the resources and information she wants other members of the DCI's community to have access to.

As of instantiating the structured activities, such as the academic program, we started with the detailed specification of two use cases: registration and defense. These use cases involve all actors, require many interactions amongst them, and require services that can operate optimally over an optical network. The registration process involves the actor 'public' (potential student) who needs to share and present her intentions and portfolio to a potential supervisor; the supervisor introduces her research lab, team, and facilities, as well as expectations and requirements. The use case 'defense' involves the program 'manager' in the organization and ruling, and requires students to present and demonstrate their results (demos); members of the jury need a high performing network connection to share their views and discuss relevant issues. Obviously, many of these services are common with the services needed for immersion in scientific activities and communities.

5. 4. A Network Infrastructure

A ligthpath provides a scientific community with a network which is highly efficient, secure, and private. Such a network is currently being constructed between several universities in Canada and European partners in the field of Technology-Enhanced Learning. Called SCORE*, this program aims to support and test innovative ideas in the area of research training. The network architecture is illustrated in Fig 6. The SCORE ligthpath network is currently being implemented and tested in the BEST project to ensure it supports the DTE and the services it offers, such as videoconferencing, 3D models and simulations, and high resolution vizualisation. CANARIE provides the ligthpath connectivity within Canada over CA*net4 (Canadian backbone) and with the European partners, in conjunction with the SVL action of the Kaelidoscope network of excellence . The first measures proved to be close to theoretical values, including when testing with the University of Twente in the Netherlands.

A range of services is needed to support immersion and access to instrumentation. Integration of these services - videoconferencing for example- onto the network is a challenge in terms of quality of service (QoS) and of security.

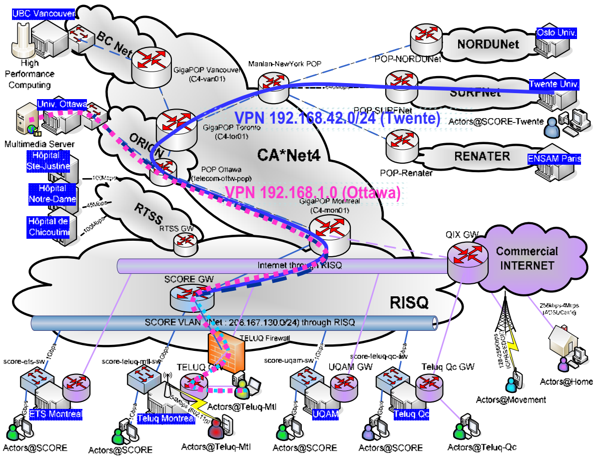

Fig. 6. The SCORE network architecture

An AccessGrid server has been configured to support multiple video-communications over this private optical network, since the network is not open to Internet and has no DNS infrastructure. It was tested with participants in Ottawa and Montreal visualizing and discussing a demo running jointly with video recordings. Participants expressed their satisfaction about the quality of the communication. Another test will involve Vancouver and use the multipoint Access Grid mode. The multicast IP technology has been configured in order to improve the quality of service by reducing the latency in transmitting an audio and video flow duplicated to distributed participants. We expect this solution to provide an improved quality over the MCU Polycom since instead of sending a mosaic of low resolution images of participants, Access Grid will send these images with their original resolution.

Further development and testing include 3D applications, models and simulations, and high resolution visualisation.

5. 5. An E-controlled Experimental Lab

How can remote teams access experimental research laboratories? This is the challenge faced by the LORIT@D team in the BEST project. LORIT* is a Télé-université experimental research lab that allows the observation and capture of multimedia data from multiple pre-synchronized sources [17] In order for distributed teams to be able to conduct remote experiments, E-control is currently being implemented to allow observation, manipulation and data collection from remote or distributed locations, therefore called LORIT at a distance, or LORIT@D (Fig. 7).

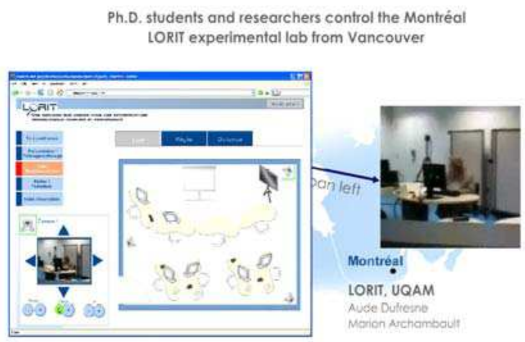

Fig. 7. The LORIT@D in action

User interface design raises specific challenges ranging from latency to cognitive load and perceptual accuracy. Such topics are currently being studied by two teams, in Montreal and in Vancouver.

The objectives of the BEST project for the LORIT@D are the following: 1) to install and program the control software for a new Web-based controller interface, 2) to study possible usage scenarios, 3) to program the controller interface for each of those scenarios, 4) to design a reservation and technical specification interface, to communicate with the technical personnel and reserve the facility, 5) to run iterative tests and experiments with users in order to solve technical and usability problems.

A new e-Controller was installed and connected with two touch panels. They were programmed to display the control of the audiovisual and telecom equipment of the LORIT: cameras, whiteboard, projector, audio and video matrices, Polycom bridges. The Web interface allows participants to control it remotely through the XPanel. Several scenarios were developed in collaboration with UBC and Simon Fraser University. A series of tests were conducted to test the technology, and to fine tune the scenarios. Further tests with users will assess the LORIT@D technical performance and usability both with and without the ligthpath connection. The ligthpath connection reduces latency to its absolute minimum. Propagation delay of the optical signal (2*45 = 90 msec for an approximate lightpath length of 4800km between Montréal and Vancouver) and a minimum transmission delay (2*8kb/1Gbps = 16 µsec for a 1Gbps optical route) provides this minimal latency. Note that this minimal latency is uncompressible and corresponds to the speed of light. Most E-control applications and remote manipulation of instruments require this reduced latency, as LORIT@D does. Another advantage of using the 1Gpbs bandwidth over a private ligthpath is to transmit high resolution videoconferencing without reducing the quality of service. Observations can be improved by an order of magnitude, and scientific discussions can be more efficient, as is needed in co-experimentation settings.

5. 6. Co-experimentations

Co-experimentations are typical activities in a 'Collaboratory', and they require a thorough preparation in terms of research protocol as well as of technical support. Aside the LORIT@D work reported in the previous section, other innovative ways of co-experimenting have been organized and investigated, at the national and international levels.

In conjunction with our partners from the KALEIDOSCOPE European research network in the field of Technology-Enhanced Learning, we prepared a co-experimentation where two research teams composed of PhD students and researchers discussed by holding a videoconference and running application sharing software [18]. Both teams used called 'Co-Lab' applications [19] to share the manipulation, observation and argumentation protocol (Fig. 9). This activity is also part of the CIEL project in Kaleidoscope. For doctoral students, this activity can