CVL@B: A COLLABORATIVE VIRTUAL L@BORATORY DEVELOPMENT AND EXPERIMENTATION

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ABSTRACT

Our context of research is in the field of the CEHA (Computing Environments for Human Apprenticeship) and particularly the DE (Distance Education). It presents a very important facet of experimental teaching. The aim of this paper is to propose a multidisciplinary architecture called CVL@b (Collaborative Virtual Laboratory) for the virtual experimentation on the Web. This architecture allows learners to perform distant practical work (Tele-PW) and experiments using virtual devices in experimental sciences in a collaborative way. The trainers could lead interactive sessions of instructions of Tele-PW using appropriate scenarios, thus using the metaphor of the distant practical worksheet (Tele-PW sheet). CVL@b is a collaborative virtual laboratory for the realization of the Experimental Work (EW). Its design was based on the analysis of the classical laboratories. In order to validate its effectiveness in a real situation, an evaluation was carried by real users. In this article, we first of all present the transition of a conventional Lab to Tele-Labs. Then, we present the CVL@b architecture. After that, we show the selected method for the evaluation of CVL@b also the parameters to be evaluated. Then, we present the got results. We finish with a discussion and a conclusion of this evaluation.

KEYWORDS

Virtual labs, e-learning, ICT, Tele-PW, Tele-collaboration, Experimentation.

1. INTRODUCTION

The use of ICT (Information and Communication Technologies) in Education gives an opportunity of online theoretical training based on interactive courses. These training environments promote the achievement of several educational objectives; the problem of practical training (effective realization of the laboratory experiments across the network) is not yet very resolved. Even though in many educational topics, especially in experimental sciences, the practical training is a must complementary to any theoretical education. In addition, conventional laboratories have a number of limitations; the time slices (assigned for PW) are limited in the students’ schedule which implies that the learning session (practical works in our case) may not take place in the most beneficial way for certain groups. In most cases, the task to be performed is discovered at the start of the session. Even if the description of this task is distributed before the session, very few learners will read.

In addition to the contexts of distance learning platforms, more generally, the digital work environments and the virtual universities, the concept of virtual lab (VL) has been developed. A VL is a digital environment aims to teach (using simulated experiments) practical approach of an experimental discipline such as physics, chemistry, mechanical, etc. It also explains concepts and rules used to describe and explain the phenomena concerned by the simulated experiments. Although these VL have been criticized [Grant, 1995; Canizares, Fetal Heart Rate, 1997], they certainly have a number of significant advantages [Swinnen, 1993; Shin, 2002]. Recently, many virtual labs [Students, 2002; Baudouin, 2007] have been developed; however, our research shows that the majority of these attempts have limitations:

- Design Approaches: Absence in the literature of a generic model for the environment of type virtual labs.
- The support and control of the learner: the situations of teaching/learning of Tele-PW can be considered dynamic or evolving situations. This dynamic characteristic requires from the tutor in charge of these
instructions a certain number of specific activities to build cognitive competences. ICT offers the tutor means of supervising, controlling learning situations, and giving effective feedbacks [Mechta et al, 2012].

— The collaborative work: The digital communication tools allow (for example) learners to work together on Tele-PW which make the resources more efficiently. This evolution of technologies created new forms of collaborative work with their own specificities. Two learners who work together to achieve a remote labs share different information about their common goal. But exchanging of information remotely may quickly become laborious and prevent them from accomplishing their activities. They can share a digital workspace where they express their ideas, communicate and exchange resources. In this case they will be confronted with a new work environment. Therefore tailored solutions must be proposed to respond to their specific needs in terms of collaborative work.

— Simulations: The kernel of these VL is the educational simulation that represents the experimental activities. Even though these simulators offer a number of advantages, they have limitations. The corollary risk is the loss of context if it has not been taken into account in the models. How close is the simulator to the real world depends on the accuracy and quality of the models on which the simulator is based. The majority of existing VL use simple animations and the learner is only an observer. Therefore, the use of the interactivity is a remedy to these risks.

— Generality: The existing VLs are all of a specific nature; each one deals with a single aspect of a discipline, such as electricity in physics, electronics or chemical experiments [Girault et al, 2003; Gerval, The Ru, 2006].

Our work therefore, proposes solutions in order to avoid these limitations. In order for these solutions to be effective, they must improve the quality of learning, but with a reasonable effort the development of these models. This requires systems that are easy to integrate, install and use. Thus, designing a model for collaborative virtual laboratories becomes a necessity. The existing platforms for distant training (Clarooline\(^1\), Ganesha\(^2\) and Moodle\(^3\)) are not suitable because they offer no structuring to these types of activities. In addition, the environments for the collaborative work (groupware) are not all adaptable for use in an educational context.

2. FROM CONVENTIONAL LABS TO TELE-LABS

The learner is the most active actor in a learning situation. He seeks to complement the acquired theoretical knowledge through the realization of PW. In a conventional laboratory, when a learner wants to resolve a PW, he/she must read the relevant PW sheet. In order to accomplish the work, the learner manipulates instruments and uses products. During all phases of a lab, the learner is responsible for taking notes or keeps records of the results. The teacher can support learners and assess their work.

The limitations of conventional laboratories in certain situations and advantage offered by ICT, made us think about the possibility of realizing practical works remotely within a new structure (Tele-labs) as shown in Figure 1. The transition from the conventional to the distance mode has therefore introduced new concepts: Tele-laboratories, Tele-PW and Tele-PW sheet. The Tele-laboratories are digital environments designed for the performing of Tele-PW. There are two alternatives of these laboratories: the remote labs and virtual labs. The remote labs are the environments where learners can interact remotely with real experiences unlike the virtual labs. A Tele-PW sheet is an electronic document containing the scenarios of the Tele-PW. The Tele-PW are a very interesting alternative to the conventional PW [Bouabid, Salmi-Bouabid, 2005] graces the economic gains and the opening to the public who did not have access to sophisticated technological equipment for this kind of learning situation. In more, a Tele-PW is the opportunity for excellence for intense exchanges between learners and tutors promoting cognitive conflict and thus facilitates individual learning and collaborative through social interactions.

\(^1\) http://www.projet-pulme.org/claroline
\(^2\) http://www.projet-pulme.org/ganesha
\(^3\) http://www.projet-pulme.org/moodle
3. CVL@B ARCHITECTURE

In our context, we want to provide a solution to the question of allowing learners to perform PWs from distance to complement and improve the teaching/learning process. This solution is aimed at solving the problems encountered in this new situation. Because of these reasons, we focus on virtual laboratories platforms in order to overcome the problems of conventional laboratories and offer to learners/teachers a pleasant architecture dealing with different scenarios in the Tele-PW. In this section, we propose an architecture including the creation of different systems. These systems work in harmony in order to provide services for the teaching/learning community of the virtual lab.

CVL@b architecture is structured based on three architectural levels (GUI, CVL@b kernel, and storage space). The kernel is composed of two main systems CVL@b-LCMS (Learning Content Management System) and CVL@b-LMS (Learning Management System). CVL@b-LCMS is designed around a learning content management (LCMS-PWS) [Mechta et al., 2007b] and documents management literature embodied in an electronic library (LCMS-EL) [Harous et al., 2006]. CVL@b-LMS is responsible for the management of learning process through a set of sub-systems: 3D environment of Tele-PW, supervision & Control system (LMS-SCT; Supervisor and Control Tool) [Mechta et al., 2012], Tele-collaboration system (LMS-SCA) and finally the learners’ assessment system.

3.1 Registration System & Interactions System

Before any action is performed via CVL@b, the users (learners, teachers and administrator) must register. After this phase, the user can connect to access CVL@b and disconnect when he/she wants to close the session. The Interactions System treats the set of interactions present in the platform. These are actions that help to introduce certain dynamism into CVL@b. In our architecture, there are three types of interactions: Human-System interactions, Human-Human interactions and System-System interactions. The interactions between the various actors, the pedagogical resources, and the virtual laboratory are carried out via an interface [Harous et al., 2008]. In order for the users (teachers, tutors and learners) of CVL@b to achieve their tasks, communication tools are available to them. These tools are either asynchronous (Mail or Forum) or synchronous (Chat).

3.2 The 3D Environment of Tele-PW

The 3D environment of Tele-PW [Doula et al., 2009] is an interactive, Tele-immersive workspace which also simulates, in real time, real training scenarios as close as possible, even to create imaginary scenarios that cannot be realized in the real world. The modeling of this environment is done based on synthesized images to get the learner’s competence within the framework of an activity working on virtual objects which leads to the use of virtual reality techniques [Mechta et al., 2007a].
3.3 Tele-Collaboration System

Collaborative learning leads to independent learning by the learners. It depends on a pedagogy based on interactive communication between learners where the teacher remains the master. This interactivity take into consideration of what the learners can do for each other. The collaborative Tele-PW [Grant, 1995; Camizares, Fetal Heart Rate, 1997] are a form of apprenticeship that requires group work where the learner performs tasks, expresses ideas, shares tools, communicates with other learners, etc. The presence of a Tele-collaboration system (CVL@h-SCA) part of CVL@h is essential to ensure certain features such as: the management of learners’ groups, coordination/synchronization of tasks (accomplished by learners in collaboration) and sharing of group members’ workspace. CVL@h-SCA is structured as follows:

—Communication tools: synchronous (Chat) and an asynchronous (mail or forum) tools are provided to CVL@h users [Harous et al., 2008].

—Common workspace: we have developed a shared workspace where Tele-PW is performed. The synchronization in this workspace is provided by the system of collaboration; each movement or operation carried out in the workspace for any learner is synchronized with all group members shared workspaces.

—A shared editor is available for users to write/edit their reports.

3.4 Pedagogical Content Management System

The PW’s descriptions represent basic educational resources and require a system for their management. In order to be able to achieve of the PW, learners should follow the steps of PW [Mecha et al., 2006]. During this phase, learners design their PW by extracting the set of virtual objects considered indispensable to do the experiment base on the PW sheet. This PW sheet in the conventional laboratories is a manuscript which is used to guide the learners throughout their activities to accomplish the PW.

Within the framework of CVL@h development where the work environment is completely digital, the idea of digitizing the PW sheet is necessary, in order to adapt to this environment. Therefore, the classic PW sheet is now considered as an electronic educational document (Tele-PW sheet).

With the emergence of Internet technologies, ICT and the fact that it is not practicable or acceptable to make learners travel to a specific location for an enormous amount of time to get the necessary information. Also learners would prefer to have simultaneous access to all the resources containing related information such as the courses, from any place, at any time and from any device. The contribution of the electronic libraries is well known in the educational context and its advantages in the transfer of knowledge. So the idea to design and implement a digital library proves to be a necessary tool that must be available not only to distance learners in particular but to all learners in general. The integration of the recent development techniques and the distributed digital content improves the learning pedagogical experience.

3.5 Supervision & Control System

The skills to manage, direct and supervise learners during the learning process, are necessary elements for efficient teaching and learning. There are two possibilities to support the learner either by integrating a fully-fledged support through the Intelligent Tutoring Systems (ITS) [Prévot, 1992] or involving human tutoring.

Because the ITS limitations such as the impossibility of building a model based on the learner’s knowledge that can be adapted to the learner’s needs and provide the necessary support. Then, these systems cannot be used entirely as a substitute for human teacher. Human tutoring may be considered as the best solution despite the temporal constraints (availability of the tutor throughout the activity of the learner). From a technical point of view, it is the best way suited to adapt to the learner’s needs and from a theoretical point of view, the human tutor is essential; given that the teacher-learner relationship is essential in the socio-constructivist learning approach. Also human tutoring will overcome the phenomenon of learners’ isolation stressed by the social distance.

In CVL@h, we followed the pedagogical approach APA (learning by actions) [Gomez, 1989], where the activities are of PW form. These activities are carried out in groups, group members share the space, where the experiment is performed, and write together a common report. During the manipulation process of a Tele-PW, the group of learners needs a tutor to guide in achieving their tasks. In this situation several problems will arise:
1. Since we adopted human tutoring, the tutor must be available during the time when learners are doing practical work. The question is how to overcome this temporal constraint?

2. The practical work is done collaboratively; tutor needs to know the status of each member towards the assigned task, any difficulties encountered, and the common result of different members so that he/she can take necessary steps to intervene or guide. In this case, the tutor's role becomes very complicated.

Our work is to design a computer system which allows a tutor to provide pedagogical supervision. This system supports tutor's interventions to assist learners, and allows them to perceive learner's activities remotely to respond to their requests, or make a decision to when to intervene. Our system has the following features:
- Distant learners' (as a group) activities supervision that includes consulting, and productions.
- Support for group of learners on how to communicate, share the workspace and collaborate in intra-groups.

### 3.6 Evaluation System

The evaluation depends on activities suggested by CVL@b. Indeed, the evaluation carried in the structure of a collaborative activity is not always valid in an individual activity. This evaluation in the CEHA context must be motivating for learners, encouraging supported learning activity, contributing to the learner's progress and must be cost effective from human perspective and easily maintainable.

In our work, we distinguish two types of evaluation. For the collaborative activities evaluation, we use the evaluation of the approach or more precisely the assistance to the evaluation. This kind of evaluation in CVL@b is based on the outputs of supervision and control system. The summative evaluation focuses on the performances (the productions carried out) and it is measured in CVL@b based on the submitted reports.

### 4. CVL@B DEVELOPMENT

The CVL@b systems are designed with MaSE (Multiagent System Engineering) [DeLoach et al, 2001] methodology and implemented within Jade platform⁴. The software architecture of CVL@b is based on 3 levels (Client, Web server and Application Server). The access to CVL@b is guaranteed by registrations and according to his mode. CVL@b provides suitable workspaces: one is dedicated for learners so that they can perform the Tele-PW and the other for the teachers/tutors to publish the Tele-PW sheets, to support the learners' groups and to control their activities respectively. With regard to the experimental protocol, we used two scenarios:
- Biochemistry Tele-PW [Mehtha et al, 2010]: its objective is to measure the concentration of a protein by colorimetric proportioning. It contains two phases: one requires a cooperative work and the other uses the tools for collaboration offered by the collaboration system.
- Physics Tele-PW: its objective is to measure the amount of stretch of a spring due to the amount mass attached to it.

### 5. EXPERIMENTATION

Evaluation must be adapted to the type of tool and include the various parameters to be evaluated, such as the technical features, pedagogic or ergonomics. Next we describe, the various parameters chosen for our evaluation. For the evaluation of CVL@b, various criteria were taken into account. In this study, the selected criteria will make it possible to validate the platform and to account the quality of training resulting from the use of this system. We describe below the selected criteria:

- **Satisfaction:** It is important to know if the user is overall satisfied with the use of CVL@b.
- **Ergonomic:** It makes it possible to evaluate the man-machine interaction of a computer system. This criterion takes into account the ease of use, the user-friendliness and the system usefulness. Since CVL@b consists of a set of systems, each system will be assessed in an independent way, in addition to the overall assessment.

⁴ http://jade.tilab.com
ICT Use: It is interesting to know if the ICT use during an activity of Tele-PW has an impact the learning. In our case, the aspects to take into account are the use multi-media documents to enrich the activity, the search of the documents in digital library, the sharing of information and the results.

Collaboration/Co-operation: It is important to measure the level of users’ participation. This factor includes the individual and collective participation in the training. This means that the learner has contributed to the realization of the Tele-PW, participated in the discussion with his/her colleagues about the practical problem and helped them during the activity.

Feasibility: A last significant factor to be measured is the opinion of the users about the possibility of using CVL@b to replace the traditional PW sessions (where learners have to be present in the laboratory).

5.1 Experiment

The evaluation of CVL@b was carried out for one month. The population that participated in the experiment consisted of 4 teachers playing the two roles teacher/tutor and 38 learners from 3 different colleges: College of Nature & life, College of Sciences and College of Technology at the University of Sétif I (ALGERIA). Among the participants 88.09% were females and 11.91% were males. Learners who participate were 1st year Master degree in Physiology and pharmacology, 1st and 2nd year Biology, 1st year Microbiology and 2nd year Computer Science. The majority of the learners (2nd year Biology, Microbiology, Physiology and pharmacology) participated in traditional PW the other learners (Computer Science and 1st year Biology) and the tutors did not have previously the traditional PW. Most participants is 56%, even if they had already worked with computers, almost their half very did not feel at ease to use them (29%). Among the users, 60.52% like to use the teaching software. The groups were coordinated by four tutors. The size of the groups varied between 2 to 3 learners (10 groups had 2 learners and 6 groups had 3 learners). The tutors had trained groups before. They are not bio-pharmacy specialists. But they know the different phases of the Tele-PW to be carried out. The participants (learners/teachers) did never participate in a remote experiment.

6. RESULTS

The communication tool used is considered to be very useful (71.5%) and very easy to use (93%) by the learners and the tutors. Most users (76.5%) consider the interface to be convenient.

During the realization of Tele-PW, 78.9% of learners have communicated with their tutors. As shown in Table 1 the tutor is performing his/her duties properly (100% of learners are getting the support, the group are controlled properly 100%, and 100% of tutors are aware of the groups’ activities progress.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Not at all</th>
<th>Average</th>
<th>A lot</th>
<th>Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication with tutor</td>
<td>5.3</td>
<td>15.8</td>
<td>18.4</td>
<td>60.5</td>
</tr>
<tr>
<td>Guided by the tutor</td>
<td>2.6</td>
<td>10.5</td>
<td>39.5</td>
<td>47.4</td>
</tr>
<tr>
<td>Aware of tutor’s presence</td>
<td>-</td>
<td>15.8</td>
<td>36.8</td>
<td>47.4</td>
</tr>
<tr>
<td>Support the learners</td>
<td>-</td>
<td></td>
<td>75.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Control the learners</td>
<td>-</td>
<td>50.0</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Aware of the groups’ activities progress</td>
<td>-</td>
<td>-</td>
<td>100.0</td>
<td>-</td>
</tr>
</tbody>
</table>

The degree of interaction (see Table 2) is considered to be important. Majority of the participants (76.3%) collaborated to clarify the Tele-PW description. 84.2% helped their colleagues during the manipulation phase and discussed with their colleagues and tutors the obtained result. Also a large number of participants (79%) have collaborated in drafting the report and almost the same percentage of learners shared the workspace. More than 90% felt the presence of other colleagues using the system that is a good indication that the users of our system did not suffer from lonesomeness which is a serious problem with online learning.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Not at all</th>
<th>Average</th>
<th>A lot</th>
<th>Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collaborated to clarify the Tele-PW</td>
<td>2.6</td>
<td>21.1</td>
<td>26.9</td>
<td>47.4</td>
</tr>
<tr>
<td>Help my colleagues in the manipulation</td>
<td>2.6</td>
<td>13.2</td>
<td>34.2</td>
<td>50.0</td>
</tr>
<tr>
<td>Discuss with my colleagues / tutors the obtained results</td>
<td>2.6</td>
<td>13.2</td>
<td>34.2</td>
<td>50.0</td>
</tr>
</tbody>
</table>
The workspace used for the experiment is considered to be very easy to use (73.4% of the users), convenient (73.8% of the users) and offer of the necessary virtual objects to accomplish the Tele-PW (78.55% of the users). The teachers and tutors consider that the designed worksheet is generic and the information is well structured. The dedicated editor is found to be easy to use, useful and its interface is a convenient. The detailed data is shown in Table 3.

Table 3. Tele-PW Template Evaluation

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Not at all %</th>
<th>Average %</th>
<th>A lot %</th>
<th>Complete %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>-</td>
<td>50.0</td>
<td>50.0</td>
<td>-</td>
</tr>
<tr>
<td>Utility</td>
<td>-</td>
<td>-</td>
<td>100.0</td>
<td>-</td>
</tr>
<tr>
<td>Convenient</td>
<td>-</td>
<td>75.0</td>
<td>25.0</td>
<td>-</td>
</tr>
<tr>
<td>Complete</td>
<td>-</td>
<td>100.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Generic</td>
<td>-</td>
<td>25.0</td>
<td>50.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Structured</td>
<td>7.3</td>
<td>21.4</td>
<td>28.6</td>
<td>42.7</td>
</tr>
</tbody>
</table>

The presence of a digital library is important. The interface is found to be very friendly (71 %). The visualization and search of documents functions are considered by the user to be convenient features to be added the classic PW.

7. DISCUSSION

The overall result of the evaluation shows that CVL@b is an acceptable tool as shown in Table 4. The majority participants find it easy to use, useful and convenient. Almost all participants think CVL@b could be used to replace a traditional laboratory. But 28.9% of the participants think that it does not improve the quality of learning at all.

So overall, CVL@b is well accepted by the users. It allows learners to exploit all the functionalities in order to accomplish their Tele-PW in an acceptable way and the tutors to monitor and support the learners using supervision tool in an efficient way,

- Feasibility: Based the participants’ opinion, who evaluated CVL@b, it is tool that can be adapted to perform Tele-PW. Learners have been able to realize the different phases of an experiment remotely with ease and the tutors are able to manage the remote sessions well.
- Satisfaction: 58.77% of the participants were satisfied in using this virtual environment.
- Ergonomics: CVL@b is considered to be useful by 71.59%, convenient by 50% and easy to use by 95.66% of the participants. All the sub-systems: communication tool and the workspace obtained are highly evaluated an ergonomic level.
- Collaboration: the level of collaboration or the degree of interaction between learners is very important.

Table 4. CVL@b Overall Evaluation

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Not at all %</th>
<th>Average %</th>
<th>A lot %</th>
<th>Complete %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of use</td>
<td>2.17</td>
<td>2.17</td>
<td>34.8</td>
<td>60.86</td>
</tr>
<tr>
<td>Useful</td>
<td>4.51</td>
<td>23.90</td>
<td>54.22</td>
<td>17.37</td>
</tr>
<tr>
<td>Convenient</td>
<td>10.90</td>
<td>39.00</td>
<td>21.85</td>
<td>28.25</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>6.50</td>
<td>34.73</td>
<td>17.42</td>
<td>41.55</td>
</tr>
<tr>
<td>Replace the Real Lab</td>
<td>2.60</td>
<td>18.40</td>
<td>21.10</td>
<td>57.90</td>
</tr>
<tr>
<td>Learning Quality</td>
<td>28.90</td>
<td>42.00</td>
<td>23.80</td>
<td>5.30</td>
</tr>
</tbody>
</table>

8. CONCLUSION

Learning in conventional laboratories remains very limited so the move towards virtual laboratories is a promising approach these days especially with ICT and Internet development and availability. This virtualization associated with the remote access brings a relevant solution to the problems of Practical works’ simulation. In this paper, we presented the design and implementation of a generic architecture of a virtual laboratory. On one hand, this virtual environment allows learners to perform virtual experiments through the
use of the experimental simulation in a collaborative/cooperative way. This collaboration increases the flexibility of the process of accomplishing a Tele-PW. On the other hand, it provides the teachers a tool to edit the Tele-PW description and the possibility to monitor and assist the learners. So CVL®b ensures that remotely experiments are performed efficiently, while the teaching aspects and the learning modalities are considered. We tested CVL®b in a real context. Thus learning the teachers/tutors gave their impressions to us about the various systems which compose CVL®b like their general opinion on the complete system. In this experiment, CVL®b was very satisfactory and allowed us to confirm that our design was well adapted to the Tele-PW and consequently to validate this platform.

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