Laboratory E-Notebooks: A Learning Object-Based Repository

Ilior Abari* – Samuel Pierre* – Hamadou Saliah-Hassane**

* Laboratoire de recherche en réseautique et informatique mobile, École Polytechnique de Montréal
** Centre de recherche LICEF/CIRTA, TELUQ - Université du Québec à Montréal

1. Introduction

Not only has email changed the way we communicate, but the Internet also modified the way learners acquire skills and knowledge. Meanwhile, distance learning has evolved from its classic framework, from the snail mail delivery of instructional contents, towards e-learning modeled on telecommunication networks. In science and engineering, theoretical instruction is generally supplemented with laboratory assignments (Lazarowitz et al, 1994). In the telelearning environments of those fields, networked virtual laboratories allow students to carry out such assignments. Hence, networks constitute a critical component of the new knowledge society.

This paper addresses the following instructional scenario: a distributed virtual laboratory platform provides a set of equipment to a class of geographically distributed learners. Learners are assigned to various groups, and each group must produce an assignment. Each assignment corresponds to a specific virtual laboratory application that exploits the platform resources. For example, such an application could allow distance interactions with equipment to corroborate a physics law (Saliah, 1999). Each group is a *learning community* whose operations rely on teammates' interactions and learners must coordinate their activities to successfully complete an assignment. The electronic notebook allows them to share data to this end. This challenge has already been addressed by Myers et al (2001). Their solution was implemented with scripts (JavaScript and CGI). The approach taken in this paper is somewhat different.

In fact, it uses Java Server Pages and servlets, and it organizes notebooks according to the fields and subjects depending on the course curriculum. In this context, a notebook is composed of a series of paragraphs, rather than a set of pages and chapters. Also, we consider each paragraph to be a learning object. The rationale behind this is simple: due to their granularity and the metadata standards

used, learning objects allow the interoperability, reuse and exchange of pedagogical contents. Nevertheless, one may wonder how the page of a laboratory notebook could constitute a learning object. In fact, a paragraph (for example, the picture of an experimental setup) may be reused to reach a course objective.

The remainder of this paper is organized as follow: Section 2 introduces the concept of electronic notebooks. Section 3 addresses metadata and learning objects standards. Section 4 presents the architecture of the repository. Section 5 describes the implementation and its results while Section 6 offers a conclusion.

2. The Concept of Electronic Notebooks

When carrying out an assignment, the e-notebook is used by all participants who wish to share information with team members. A different notebook is used for each session. Learners can only access the notebooks associated to the groups to which they belong. The information included in a notebook can only be deleted by the author. According to the CENSA (Collaborative Electronic Notebook Systems Association), "an electronic notebook is a system to create, store, retrieve and share fully electronic records in ways that meet all legal, regulatory, technical and scientific requirements. By "system" we mean the right combination of policies, procedures, technologies, and regulations." (Website #1)

- The Personal Electronic Notebook System (PENS) is designed for the independent professionals (e.g. lawyers, doctors, business people). It replaced the traditional notebook and can include sophisticated functionalities such as Web search;

- The Collaborative Electronic Notebook System (CENS) favors connectivity, communication and teamwork. It relies on PENS in order to support and favor collaboration and allow information to be shared among a work group. This type of

Abstract

During distributed virtual laboratory experiment sessions, a major problem is to be able to collect, store, manage and share heterogeneous data (intermediate results, analysis, annotations, etc) manipulated simultaneously by geographically distributed teammates composing a virtual team. The electronic notebook is a possible response to this concern. In this paper, we present an electronic notebooks repository using LIP and LOM metadata standards. This repository is implemented as a learning object database. According to the curricula, the notebooks are classified by teaching fields and subjects. Simulation results show the effectiveness of such representation, particularly in terms of response times required to carry out transactions when operating the repository.

KEY WORDS: e-learning, telelearning, virtual laboratory, metadata, learning object, collaboration, notebook, paragraph.

notebook is particularly relevant to virtual laboratories.

Consequently, we may conclude that the rationale behind lab e-notebook is the production and dissemination of data during virtual laboratory sessions. Lysakowski (1997) claims that in companies such as DuPont or Air Products, lab workers spend from 15 to 25% of their time filling out paper reports by hand. However, such reports cannot be shared instantaneously. He also mentions that the authors of such documents are qualified personnel and that computerization would further streamline their tasks. A collection of e-notebooks is called a repository. In an online learning environment, the repository is a computer unit which hosts pedagogical contents. It must be open to facilitate access and usage. Hence, standards become necessary.

3. Metadata and Learning Object Standards

Metadata are considered a strategic theme in e-learning and engineering debates. But how do we define metadata? Literally, metadata is data about data. More specifically, it is a set of attributes which describe an object. For example, consider the label added to pharmaceutical products. Such a label is so important, that it is basically prohibited by law to sell those products without a label. However, when purchasing a product, consumers are interested in the product itself, not in its label. Also, if these labels are designed according to a standard, and that they are computerized, it would be easy to find all of the pharmaceutical products which meet specific needs, that is to say a set of standards. Contrary to the current Web search engines, the response to such a request would provide solely the requested products, and nothing else. Thus, such an approach would enhance relevance.

Metadata provide an effective solution to identify, define, classify and find objects. The term "object" refers to a resource, an actor, or an action. Hence, a course may be custom-made, or designed on the fly, at the moment a course server receives a request. To do so, the application selects and combines various contents from a variety of sources (scratching) that are totally adapted to the context. In this case, we are in the presence of "learning chunks". This perspective, along with emerging content providers and consumers, matches a worldwide movement in training and distance education. The PRÉAU, a technology watch team of the Paris Chamber of Commerce and Industry (Website #2), claims that "it is critical to master metadata as the model manages project interfaces, controls communication and workflows, and directly affects the instructional model" (Préau, 2002).

Metadata constitute another step towards the semantic Web, and their standardization offers many advantages. Upstream, the best practices set up by teams of professionals evolve progressively towards methodological tools. Downstream, evaluation criteria emerge to allow quality control, thus enhancing consumers' confidence and contributing to market developments. The main actors for metadata standardization are the Dublin Core Metadata Initiative, IMS Global Learning Consortium, ARIADNE, IEEE Learning Technology Standard Committee (LTSC), the US Department of Defense (Project ADL; Website #3), the AICC (Aviation Industry CBT Committee). The implication of these organizations shows the importance of the stakes. Their work is complementary; they use each others' results to further advance knowledge (Chung et al., 2002).

Designing an open metadata-based distance learning infrastructure requires a standard description of the learning contents and the information package associated to the target learners. Hence, the learning contents is encapsulated into learning chunks, called learning objects. Learning objects are described through a standard set of metadata. This approach requires that instructional design respects two concepts: *granularity* and *combination*. Granularity requires learning objects to be as elementary as possible; combination indicates that each course is a sound arrangement of such objects. The ultimate goal is to dynamically generate custom-made course which are adapted to a learner's specific needs (Wiley, 2000). The difficulties experienced by conventional training institutions in response to custom-made learning underline the amplitude of such a challenge. Learning Object Metadata (LOM) is the metadata standard suggested by IEEE. It provides a semantic model which describes the learning objects properties, regardless of the manner and context in which they are used.

4. Architecture of the Repository

E-notebook repositories bear a multi-level hierarchical structure. Each virtual laboratory platform supports a single repository. A

repository contains all of the completed assignments organized according to various fields. Each field is composed of several subjects, and each subject includes different assignments. A different notebook is assigned for each assignment session in which a team participates. A notebook is composed of one or many paragraphs and each paragraph corresponds to a learning object. This architecture is illustrated in Figure 1.

When adding a specific virtual laboratory to a platform, the administrator creates an initial notebook that includes the assignment instructions. A copy is available for each group registered for the laboratory. Then, teammates can use it to share the information they need to accomplish their collaborative task. Notebooks are kept in a database that is hosted on the server platform. Each member may create, modify or delete paragraphs. But only the author can delete the info s/he created. Each paragraph is assigned a unique ID number and its creation and subsequent modifications generate a notice sent to all of the learners who are using the notebook. For example, imagine that learners L1 and L2 are both working on notebook N, which contains paragraph P. If L1 modifies P, then L2 is informed. Then, L2 may decide to ignore the modification or refresh the notebook version he is using. Learners create paragraphs when they wish to save and share certain information with teammates. Learners are identified through a set of metadata and each one has a unique PIN (Personal Identification Number).

5. Implementation and Results

We chose to use the Learner Information Package from IMS (Website #4) to identify the learner. For the sake of clarity and simplicity, only the "Identification" category will be considered. As for the contents, numerous metadata standards have been suggested (LOM, SCORM, ARIADNE, Dublin Core). LOM from IEEE (Website #5) was selected for the purpose of this investigation.

As for the operations, as shown in Figure 3, a repository interface is used to create, search, modify or delete notebooks, and notebooks offers the same functionalities for paragraphs. Also, a paragraph is a Java object that members listen to. It informs them of new events and updates. The Database Management System (DMS) administers simultaneous accesses and ensures data security. Microsoft Access 2000 was the prototype used in this investigation.
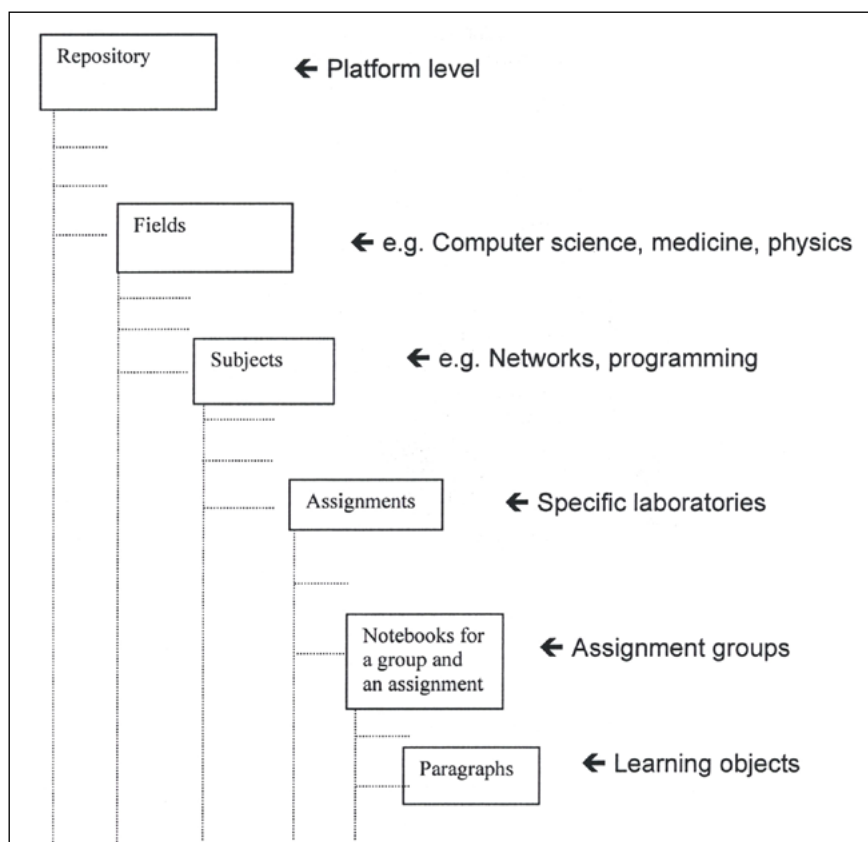

Figure 1. A Typical Architecture of an E-notebook repository

5.1 Overview

Learners download a paragraph editor (Figure 2) from the virtual laboratory server platform and install it on their computers. When a user logs on to the system, an SQL request is sent to the server to retrieve the notebooks available for this specific account. A servlet and a request response is returned in a JSP (Java Server Page). Then, if the learner selects one of the notebooks displayed, a second SQL request is sent to the server to find the corresponding paragraphs. The result is displayed in the paragraph editor. The paragraph editor includes four sections (See Figure 2): the menu, the notebook tree structure (upper left corner), the event notification area (upper right corner) and the actual editor (bottom section). The paragraph selected by the learner appears in the bottom section. The File menu allows users to save data on the database, to import or export paragraphs to other software (e.g. a word processor or spreadsheet).

When a learner validates a modification or addition to a paragraph, the database is updated and a notice is sent to all of the notebook users. The *Metadata* notebook allows users to create, modify or consult metadata associated to a paragraph. Finally, the *Print* menu allows users to print a paragraph, a notebook or its metadata. When a paragraph is added, the metadata interface (See Figure 3) is automatically displayed. However, when a learner modifies a paragraph, he/she must select *Metadata*, then *Modify* to update the metadata, if necessary.

As for the server, the platform administrator creates the learners' accounts, the virtual laboratories, the groups and assignment sessions. He/she also registers groups for specific sessions. To create a learner's account, he uses the interface shown on Figure 4. For example, the section "Affiliation" corresponds to a category bearing the same name in the LIP standard. It is used to enter all of the organizations a person belongs to, as well as his or her status and date when they joined the organization. Those are useful search criteria. Since people can belong to more than one organization, the button *Add* allows to enter a list (on the right). The button *Remove* permits the removal of an element from the list for modification purposes, and *Erase* is used to delete an element. The *Close* button (bottom right corner) allows a user to close this file.

The *Referential* section is used as LIP differentiates each learning object provider (hence, its repository as well). Thus, we refer to a unique Learner X in Repository Y. This favors interoperability and data exchange among repositories. The *Source ID* metadata corresponds to the learner identification number while the *Index ID* refers to the repository. The buttons *Name, Address*, and *Contact* allow input of many names, addresses (residence, office, etc.), and contacts (phone, fax, email, cell phone). Finally, if a learner's account is created only once, the addition of paragraph may be frequent, which may make the metadata entry seem fastidious. Thus, we must compromise between using default values (initialized at the moment of programming) or searching more precise information.

5.2 Metrics and Hypotheses

One of the challenges of designing a computer system lies in the selection of metrics. The e-notebook repository is used by a team of geographically distributed learners who must share information. Hence, it is important that learners be quickly informed of the modifications
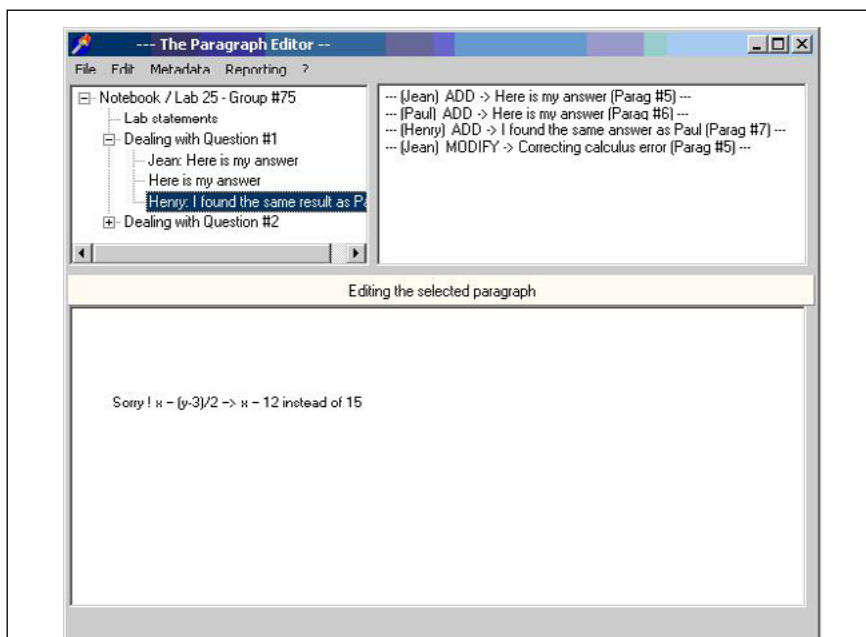

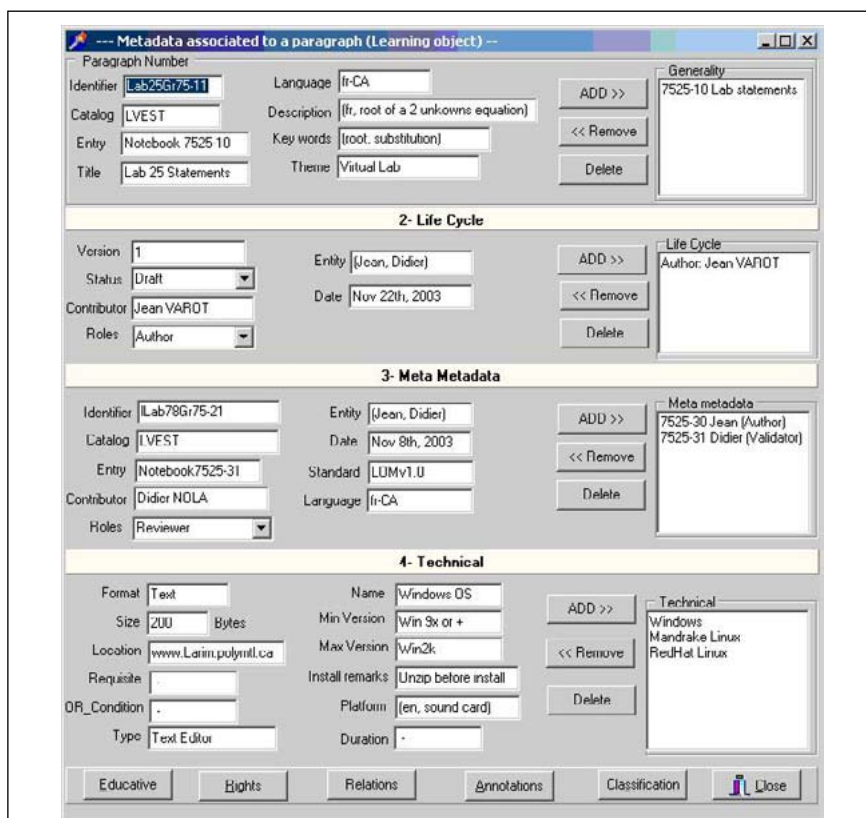**Figure 2. The paragraph editor**

Figure 3. Metadata associated to a paragraph

conducted by their teammates. Thus, the response time is the factor that best describes interactivity, so we selected this element as the experimental criteria.

Four types of operations are possible when interacting with a database: writing, reading, modifying and deleting. Writing is a mutually exclusive activity after locking. Then, it is followed by a Java notice propagation, whose delays are considered trivial. Deleting also works similarly, although it can solely be conducted by the author of the paragraph. Hence, these two functionalities are not really associated to sharing, and they cannot be combined among themselves, nor with others. For these reasons, they will be ignored in this paper and we will solely address consultations and modifications. For these two activities, simulations will be conducted with a group of three people. In fact, for pedagogical purposes, teams usually tend to be small (3 to 4 learners). Moreover, it is assumed that the platform server is sufficiently powerful to handle a large number of teams.

5.3 Notations

The following symbols will be used: C indicates a consultation and M denotes a modification. Thus, 2C + 1M means that 2 consultations and a modification are conducted simultaneously; [1C + 1M] + 1C indicates that a consultation and a modification conducted *simultaneously on the same paragraph* while *another paragraph* is being consulted. In fact, the brackets [ ] indicate a set of operations conducted on a same paragraph. Hence, although it is associated to the same quantity of consultations and modifications, [1C + 1M] + 1C is different than [2C] + 1M. Given this convention, for a team of three people, at any given moment, one of these situations occurs:
- all 3 are consulting (3C);
- all 3 are modifying an element (3M);
- 2 are consulting and 1 is modifying or vice versa (2C + 1M or 1C + 2M).

Also, as illustrated on Figure 5, each of these situations may imply one, two or even three paragraphs.

This leads us to the following experimental protocol:
- Test 1: three independent accesses to three paragraphs;
- Test 2: three simultaneous access to the same paragraph;
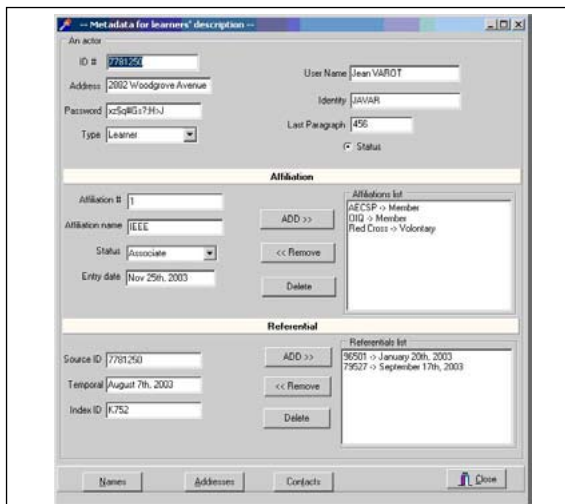- Test3: two of three accesses are simultaneous (or occur on the same paragraph);

Figure 4. Metadata used for learners' descriptions

Thus, we are in the presence of an intermediary case and two extreme cases (maximal and minimal concurring accesses).

5.4 Results and Analyses

For the purpose of this investigation, we begin with three clients. The execution time equals the average of the three response delays. The Java **GregorianCalendar** class and its *getTime()* method are used. Before sending a request to a server, each client initializes a *StartTime* variable. Then, it reads the time and writes it in the *EndTime* as soon as it receives a response from the server (for modifications, this response is a notification; for a consultation it corresponds to the arrival of the requested data). The response time equals *EndTime* minus *StartTime*.
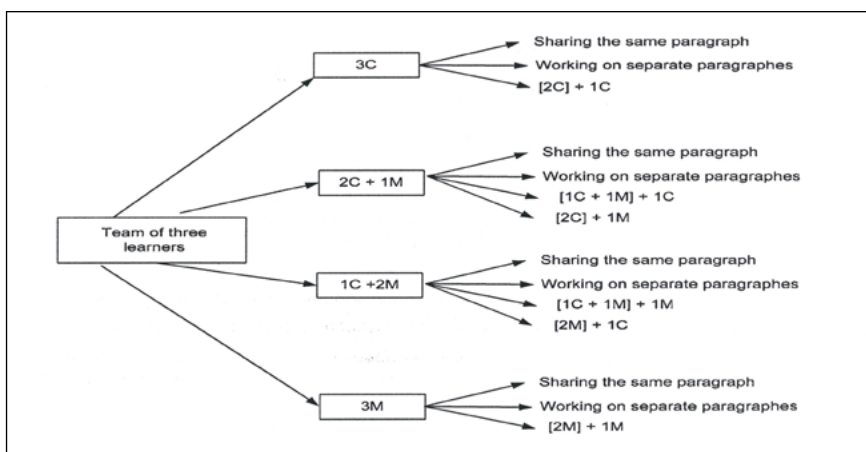

Figure 5. Possible scenarios

Test 1: Each learner uses a different paragraph

In this case, there are no concurring accesses to learning objects. The ten sets of measures conducted generate the results in Table 1:

Table 1: Test 1: Each learner uses a different paragraph

Scenario	Time (ms)
3C	462
3M	1150
2C + 1M	644
1C + 2M	925

This data is illustrated in Figure 6.

Results Analysis for Test 1: the mean response time of consulting three different paragraphs is about 462 milliseconds, which is relatively fast. However, as soon as one of the consultations becomes a modification (2C + 1M), the response time increases by about 40%. Of the four scenarios investigated, 3M is the least favorable with a response time that is 2.5 times superior to 3C. This first test indicates that compared to consultations, modifications are more costly in response time. In fact, a consultation simply implies data reading.

Test 2: All of the teammates are using the same paragraph

In this case, accesses are totally concurring. This yields results in Table 2.

Table 2: All of the teammates are using the notebook

Scenario	Time (ms)
3C	477
3M	1908
2C + 1 M	1193
1C + 2M	1622

These results appear in Figure 7.

Result Analysis for Test 2: three simultaneous consultations of a same paragraph (3C) yields response delays which are almost identical to those of Test 1. (477 ms vs 462 ms). In fact, as these consultations were associated to reading, it does not make much difference whether learners are using a same paragraph or not. The 3M scenario is very costly as data is locked by the first learner who sends his request and the next learner will be served only when the first one finishes. Moreover, the third learner also experiences bottlenecks as he will only be served once the second learner has completed
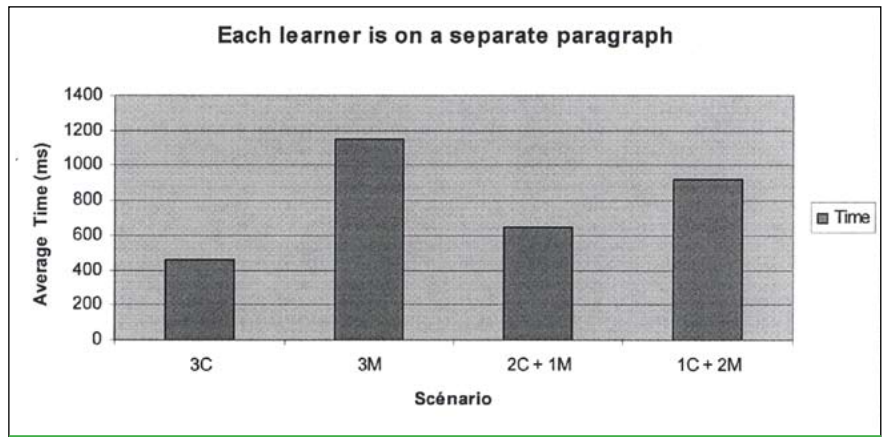

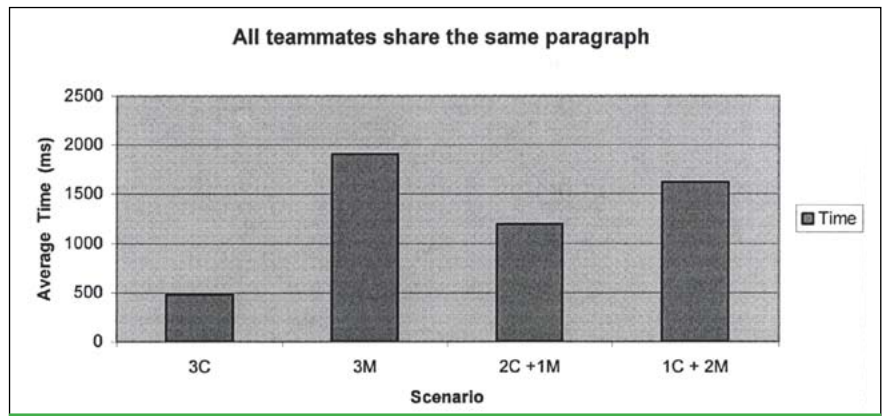**Figure 6. Response delays for Test 1**

Figure 7. Response delays for Test 2

his updates. The mean response delays, which were 1150 ms in Test 1 increases to 1908 ms, a 66% increase which is mainly due to concurring accesses and inducted locks.

Test 3: Two of three learners are using the same paragraph

In this case, contrary to Test 1, we are in the presence of concurring accesses. However, they are relatively less numerous than those in Test 2, where all three users are simultaneously using the same paragraph. Using the same measures, we obtain the results in Table 3:

Table 3: Test 3: Two of three learners are using the same paragraph

Scenario	Time (ms)
3C	469
[2M] + 1M	1688
[1C + 1M] + 1C	844
[2C] + 1M	657
[1C + 1M] + 1M	985
1C + [2M]	1595

These results are illustrated in Figure 8.

Results Analysis for Test 3: [2C] + 1C yields similar results to 3C in Tests 1 and 2. This was to be expected, as consultations are not really affected by concurring accesses. The response delays for scenario [2M] + 1M is most similar to the three simultaneous modifications conducted on the same paragraph (3M in Test 2) than those of Test 1, where modifications show no correlations (3M in Test 1). Also, we notice that [1C+1M] + 1C causes longer delays than [2C] +1M. This is due to the fact that in the latter scenario, modification, which is the most demanding operation, occurs separately. Thus, [1C + 1M] + 1M generates faster delays than 1C + [2M], even if both scenarios are associated to the same number of consultations and modifications.

Results Synthesis

Table 4 summarizes the results generated by all three tests.

Table 4: Result Synthesis

Scenario	Test 1 (ms)	Test 2 (ms)	Test 3 (ms)
3C	462	477	469
3M	1150	1908	1688
2C + 1M	644	1193	-
1C + 2M	925	1622	-
[1C + 1M] + 1C	-	-	844
[2C] + 1M	-	-	657
[1C + 1M] + 1M	-	-	985
1C + [2M]	-	-	1595

A hyphen indicates that the corresponding scenario does not exist for that test. These results are illustrated in Figure 9.

Figure 9 shows that the response delays associated to consultations are very similar for all three tests. This is not the case for modifications. Also, the most costly operations are simultaneous modifications on a same paragraph. However, given that paragraphs are increasingly granular, the likelihood of this happening is very low. Thus, this offers further support that the movement towards granular learning object constitutes a step in the right direction. Table 5 and Figure 10 show however a decreasing performance with more teammates working on the same paragraph, but this is not a realistic scenario.

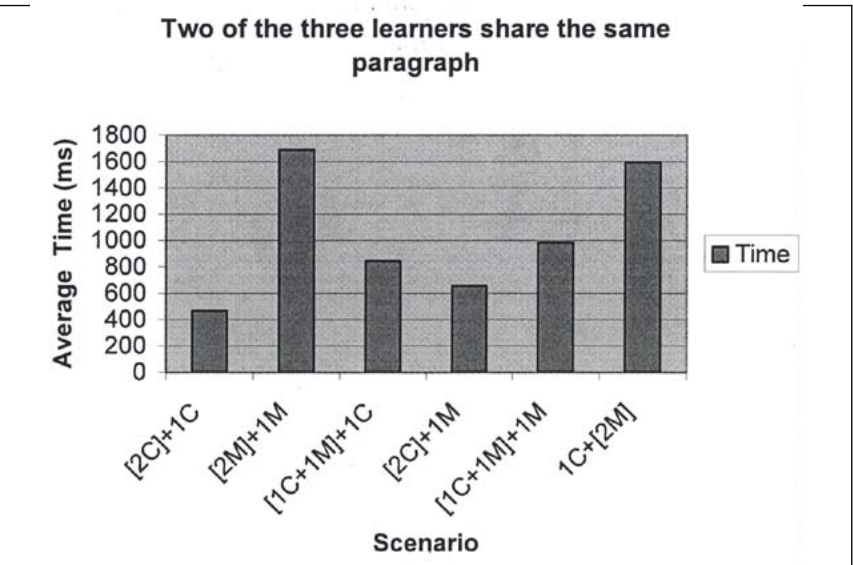Table 5 shows a decreasing performance with more teammates

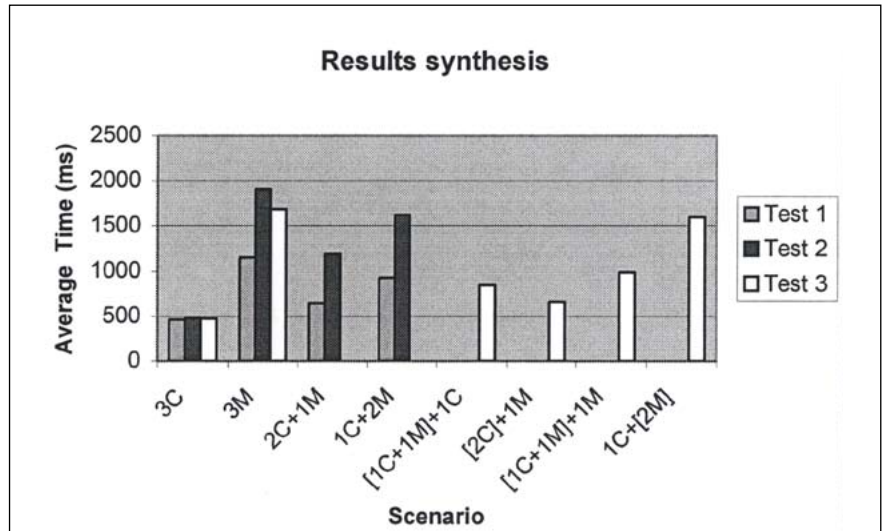

Figure 8. Response time for Test 3

Figure 9. Results Synthesis

Table 5: Result Synthesis

Seven teammates sharing the same paragraph	Scenario	Time (ms)
	7C	476
	6C + 1M	1197
	5C + 2M	1630
	4C + 3M	1924
	3C + 4M	2578
	2C + 5M	2925
	1C + 6M	3541
	7M	4292

6. Conclusion

This paper presents a laboratory e-notebook repository based on learning objects. The results from our investigation indicate that consultation response delays are relatively fast. On the other hand, simultaneous modifications to a same paragraph (or learning object) are more costly. Future research will address response delays, repository access security through a cryptography system with symmetric keys (for example), the flexibility to select one's preferred metadata standard (LOM, SCORM, or other) through the implementation of transcoding tables between standards. Moreover, designing a search tool that exploits metadata will further favour the development of distance learning opportunities on the Web.

Figure 10 . Response time for 7 teammates on the same paragraphe

Bibliography

Chung N., Cormenier M.N, "Ressources éduca tives numériques : normes et standards de métadonnées", in Les fiches techniques, édi té par Educnet, ministère de l'Education nationale, France, April 2002.

IEEE P1484.12/D6.4, Draft Standard for Learning Object Metadata, March 2002.

IMS Global Learning Consortium, Inc., IMS Learner Information package – Information Model Specification, Final Specification, Version 1.0, March 2001.

Le Préau, Chambre de commerce et d'industrie de Paris : Quel modèle qualité pour la e-formation ?, 2002, 154 pages.

Lysakowski R., "Comparing Paper and E l e c - tronic Laboratory Notebooks", Scientific computing & automation magazine, May 1997.

Lazarowitz, R., & Tamir, P. Research on using laboratory instruction in science. In D. Gabel (Ed.) Handbook of research in science teaching. New York: Macmillan, 1994.

Myers, J. D., Mendoza E. S., Hoopes B., A Collaborative Electronic Notebook, Proceedings of the IASTED International Conference on Internet and Multimedia Systems and Applications (IMSA 2001), August 13-16, 2001 Honolulu, Hawaii.

Saliah-Hassane H., "Mesures électroniques et télé-manipulations sur les réseaux informatiques pour la formation, l'apprentissage et le télé-travail collaboratif", Initi@tives 99: Universités virtuelles, versun enseignement égalitaire, (AUPELF-UREF), Edmunston, Canada, August 26 and 30 1999.

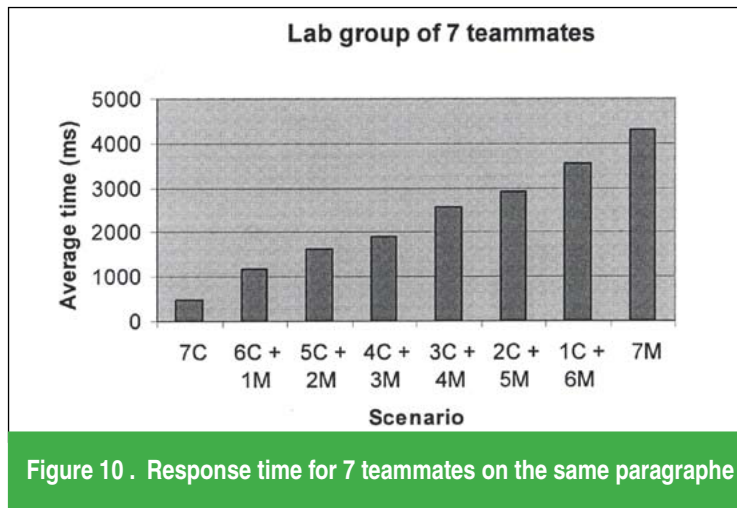Suthers D. D., Evaluating the Learning Object Metadata for K-12 Education Resources, Proceedings of The IEEE International Conference on Advanced Learning Technologies (ICALT 2001), August 2001, Madison, Wisconsin, pp. 371-374.

Wiley, D. A., "Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy", The Instructional Use of Learning Objects, D. A. Wiley (Ed.), 2000, Bloomington, IN.

Internet Websites

1. Collaborative Electronic Notebook Systems Association (CENSA), http://www.CENSA.org

2. Le Préau, "centre de veille sur les technolo gies de l'information et de la communication pour l'éducation" de la chambre de commerce et d'industrie de Paris : http://www.preau.ccip.fr

3. Advanced Distributed Learning (DoD), http://www.adlnet.org

4. IMS Global learning http://www.imsproject.org

5. IEEE Learning Technology Standards Committee, http://www.isc.ieeeltsc.org/

Abari Ilior was granted a Diplôme Universitaire d'Études Générales (DEUG) in Physics and Chemistry and a Licence ès Science in Chemistry from University of Niamey. Then he moved to African Computer Science Institute for an engineer degree. After a few years of working in a private company, he has completed his M.Sc. A at the École Polytchnique de Montréal in January 2003. His research interests include e-learning environments, specially virtual and remote laboratories.

Dr. Pierre is currently a Professor of Computer Engineering at École Polytechnique de Montréal where he is Director of the Mobile Computing and Networking Research Laboratory (LARIM) and NSERC/Ericsson Industrial Research Chair in Next-generation Mobile Networking Systems. He is the author of four books, co-author of two books and seven book chapters, as well as over 250 other technical publications including journal and proceedings papers. His research interests include wireline and wireless networks, mobile computing, performance evaluation, artificial intelligence, and electronic learning. He is a Fellow of Engineering Institute of Canada, senior member of IEEE, a member of ACM and IEEE Communications Society. He is a Fellow of Engineering Institute of Canada, senior member of IEEE, a member of ACM and IEEE Communications Society. He is an Associate Editor of IEEE Communications Letters and IEEE Canadian Review, a Regional Editor of Journal of Computer Science, and he serves on the editorial board of Telematics and Informatics published by Elsevier Science.

Dr. Saliah-Hassane has an Electronics degree from Cheik Anta Diop University (Senegal, 1976), a Bachelor's degree in Engineering, and a Master of Applied Science degree from École Polytechnique de Montréal and a PhD degree in Computer Aided Analysis and Design from the Electrical and Computer Engineering at McGill University in Montreal.

He is currently teaching Informatics and Computer Networks at Télé-université in Montreal, and is Past Program Director of École de Technologie de l'Information (ÉTI).

Dr. Saliah-Hassane PhD is a senior researcher at the Inter-university Research Center on Telelearning (CIRTA / LICEF), member of the Ordre des ingénieurs du Québec (OIQ), senior member of IEEE (IEEE Education Society and Computer Society), member of the International Conference on Engineering Education Steering Committee (ICEE-ISC), member of the International Network on Engineering Education and Research Steering Committee (iNEER) and member of the Learning International Network Consortium (LINC). Dr. Saliah-Hassane is also a Principal Investigator of Learning Object Repository Network (LORNET), a Natural Sciences and Engineering Research Council Research Network in Canada. Professor Saliah-Hassane is regularly a guest speaker in a number of francophone and international conferences involving engineering education. His reasearch interests are on Virtual and Remote Laboratories including Grid and Web services and Distributed Systems and High Performance Computing for Electrical Engineering.