Web-Based Learning Environment Architecture (WLEA)

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Abstract. The E-Learning systems represent a new philosophy in educational organizations. The main features of the E-Learning are the interactions between the instructor and the learners via the electronic instruments, and the personalization of learning material according to learner preferences. This paper introduces a Web-based Learning Environment Architecture (WLEA) which aims to define the different layers for a platform independent framework to support material interoperability, software reusability, and system scalability. It includes authoring tools for course, lesson, learning object, different media types. It includes also, synchronous services (chat, online discussions), and asynchronous communications (discussion forums, messages, queries….). The Architecture allows the existence of different user levels according to their roles and supports different educational scenarios for virtual classroom, as well as collaborative learning.

Keywords. Computer-based instruction, Interactive multimedia systems, E-Learning, E-Learning architecture, Interoperability, Reusability.
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1. Introduction

Universities, companies, and schools, are using e-learning solutions in some way. This trend toward e-learning is due to many factors such as ongoing capabilities in e-learning, and the great advance in multimedia technologies [1,2]. The E-Learning system may be defined as the delivery of training and learning materials, information, and contents to learner by integrating administrative, pedagogical, and technological models. E-learning is a multidisciplinary filed, so it needs the cooperation of

specialists in many fields and sciences to produce an integrated learning environment [3,4,9,16].

Using technology to enhance learning began with research into how people learn, and specifically, how they learn most effectively and efficiently. Researches had enumerated the following results:

- Different individuals' progress through instruction varies by factors of three to seven – even in classes of carefully selected students [5].
- On average, a student in classroom instruction asks about 0.1 questions an hour [6].
- In individual tutoring, providing increased opportunities for direct student-to-instructor communication, students may ask or answer as many as 120 questions per hour [6].
- The achievement of individually tutored students may exceed that of classroom students by as much as two standard deviations – an improvement that is roughly equivalent to raising the performance of 50th percentile students to that of 98th percentile students [7].
- Studies also, show that, in contrast to classroom learning, information technologies can adjust the pace, sequence, content and method of instruction to better fit each student's learning style, interests and goals [8].

To the best of our knowledge, we did not find in literature an article that handles the whole view of the model, but the available researches discuss the problem from certain views. Zdanowicz, *et al.*[10] showed how specifications of e-learning systems can be personalized to different learner profiles. They described course outline(s) by directed graphs called outline graphs. Then they discussed several techniques for tailoring the graph according to the needs defined by a learner profile. Aleksieva, *et al.* [17], presented the ARCADE (Architecture for Reusable Courseware Authoring and Delivery) project that used a development methodology called the Unified Software Development Process. They introduced the design principles and considerations such as open, platform independent authoring tools.

Apostolopoulos and Kefala[11,12] proposed a flexible and comp-onent-oriented XML-based e-learning services management framework taking into account several parameters concerning the educational

process, the network infrastructure, the QoS requirements, the available educational content, etc. Siqueira, *et al*. [13] proposed an e-learning framework that is composed of other frameworks that are also flexible and can be con Fig.d. It is composed of the following components: Data and Metadata Management, Groupware Management, Content Development Management, Assessment and Evaluation Management, Interface Management, Role and Security Management and Rule Management.

Cisco, [14] outlined the business drivers and benefits that justify an e-learning solution in the first place. Also, he[14] offered implementation guidelines and recommendations intended to increase the success of anyone building and enhancing his own e-learning model. Siqueira, *et al*. [16] described a generic architecture for educational and training systems from the software development point of view. They discussed that architecture according to web technology, enabling a better understanding of the involved technological aspects of educational and training systems.

Liu, *et al*. [18], proposed a functional architecture and service architecture for building standard-driven distributed and interoperable learning systems. The functional architecture defines components that make up an e-learning system and the objects that must be moved among these components. They focused on how to integrate Web Services on the e-learning application domain. Also, the UKeU learning environment supports distributed team-based course development with embedded quality assurance within its learning contents management system LCMS sub-system [19].

This paper introduces a Web-based Learning Environment Architecture (WLEA) which aims to discuss the requirements of a general qualified e-learning system from the view point of the developers, and users of the system. This is achieved by defining different layers for a platform independent framework to support material interoperability, software reusability, and system scalability. The architecture includes authoring tools for course, lesson, learning object, different media types. It includes also, synchronous services, and asynchronous communications.

The paper is organized as follows: Section 2 presents the characteristics of the qualified e-learning system. Section 3 is directed to the WLEA model introduced in this paper and discusses its layers in brief. Section 4 is dedicated to discuss the actors involved in the WLEA and their roles in the system. Section 5 discusses the logical view of the WLEA by discussing the different logical layers of the system. Section 6 is directed to the physical view of the WLEA by discussing the operational packages used in the system. Finally, Section 7 presents the conclusion and the future work.

2. E-Learning System Requirements

The e-learning system, as any software system, has two types of requirements: Learning requirements and software quality requirements. On one hand, the *learning requirements*, which are known in software engineering as functional requirements, are the requirements of the e-learning stakeholders: Learner requirements, Instructor requirements, and Authors requirements [2, 15, 17].

The *Learner* seeks knowledge, either with formal methods by attending courses, or with informal methods by just searching a customized course. The required knowledge may be found internally within the enterprise or may be retrieved using the e-learning communities through the Internet. Learner needs can be summarized in "Give me the right material at the right time that fits with my preferences".

The *Instructor* is responsible for guiding the learner through learning process. This can be achieved by Face-to-Face (F2F) interaction, or remote interaction. The instructor also follows the learner activities and works, uses tools to evaluate learners, and communicate with them. Instructor needs can be summarized in "Give me the environment that supports me to help and guide learners as most as I can, within the right time and according to learners preferences" .

The *Authors* are responsible for all authoring activities within the system. They are media, learning object, lesson, courses, and assessment authors. They can add, update, upload, download, look for, and assemble different categories of assets (learning materials) in the learning system. Author needs can be summarized in "Give me a chance to produce the

materials at the right time with the right representation that match with learners' preferences".

On the other hand, the *software quality requirements*, which are known in software engineering as non-functional requirements, are divided into three parts: Users requirements, System requirements, and Transferability requirements. Figure 1 shows the software quality requirements.
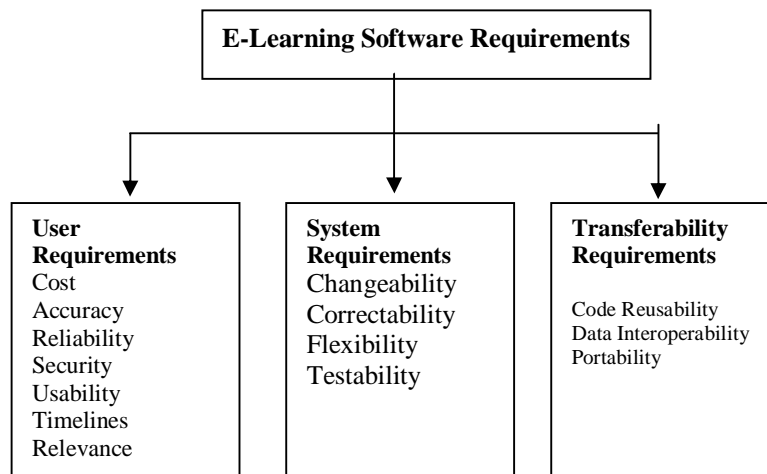
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                 ┌─────────────────────────────────────┐
                 │   E-Learning Software Requirements   │
                 └─────────────────────────────────────┘
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User Requirements	**System Requirements**	**Transferability Requirements**
Cost	Changeability	
Accuracy	Correctability	Code Reusability
Reliability	Flexibility	Data Interoperability
Security	Testability	Portability
Usability		
Timelines		
Relevance		

Fig. 1. E-Learning Software Requirements.

All the e-learning stakeholders take part in user requirements. The **cost** represents an important factor of the software requirements. There are needs to reduce the cost of the supported service. The Cost Effectiveness: Encompasses "reduction in design and development time" [20]. The cost can be reduced using reusability. **Timeliness** means the fast creation and delivery of the required material. Also, the material must be available to different users in different locations. **Relevance** is the relevance of the delivered material to the user. **Accountability** is to keep the user informed with his activities with the system.

On other hand, the *system requirements* can be summarized in one word, *i.e.* **Maintainability** which represents the ease with which the software features can be added, removed, or modified [20]. Finally, the *transferability requirements* are related to the transfer of the programs and system data. **Reusability** means the ability of a software component to be (re)used in developing various business applications [20]. **Data Interoperability** means the ability of a system's data to be transferred

between different systems. **Portability** is the transfer of executable code in different environments.

3. WLEA Model

WLEA model consists of four parts: Learning Content Management System (LCMS), Learning Management System (LMS), and Management System (MS) as shown in Fig. 2. In **LCMS**, courses master copies are prepared. The content in the e-learning system has different levels of granularities. The course consists of lessons, and a lesson consists of smaller pieces called learning objects which consist of pieces of media. This content production process needs the interaction and cooperation of the course consultant as a top coordinator for the process with other actors such as the course author, learning object author, and media author to implement the course scenario. The scenario in this paper means: the procedure to build; the way to deliver; and the style to present the material to the learner. The learning object or learning unit is considered as the smallest valuable unit in the system that fulfills one objective of the lesson objectives. This hierarchal classification is very important as it supports the system modularity, and enables the import/export on different levels of needs with other systems as will be explained in WLEA Physical View Section.

In **LMS**, the course administrator establishes instances from master courses to be suitable with each section needs. He also, prepares student groups and manages the instance course delivery according to the user's profile. The instructor communicates with the learner by engaging with the system through the instructor/learner session. So, the instructor can control the learner activities. The LMS includes modules for learner to register in instance courses and sections.

MS includes the general modules of the learning system as any common software system. It contains the general user management module, the general event management module, and the general reporting management module. It includes also, general modules for users communication, and general querying and mining modules, and finally, the general helping module.

To enable system transferability requirements, there exists an optional **community system** layer to enable system interaction with other

related learning community systems for reusing software, and inter-operability of data. It contains the importing modules and exporting modules. And also, it contains modules for copyright of material and software along with payment module for payable imported material.
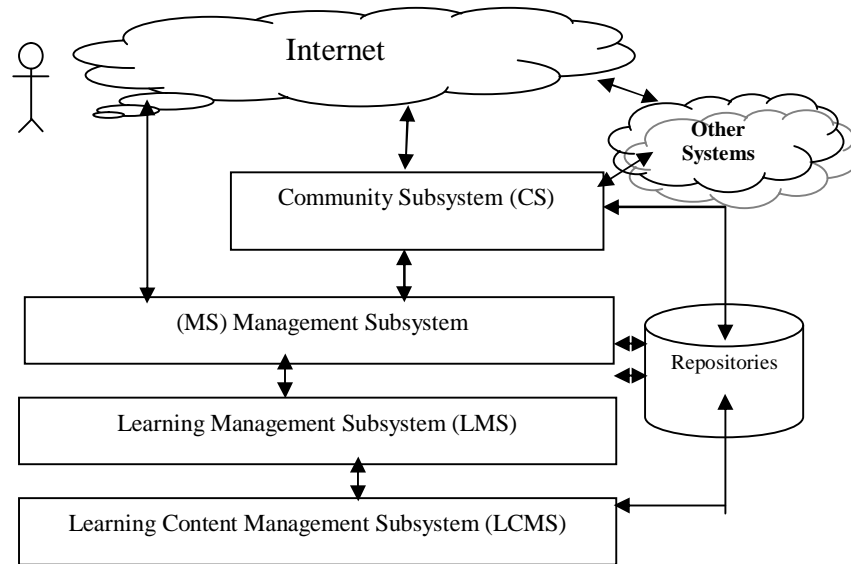

Fig. 2. The WLEA Model.

4. WLEA Actors (Requirements)

This section describes the WLEA actors and their roles, for detailed description of these roles, please refer to Appendix A. For the learning process, there are learners, and instructors. A **Learner** is any person that uses learning resources to gain knowledge or skills. Each learner may participate in more than one registered course and can access the course materials and the course environment. Learners (students) are organized in groups, for the purpose of the curriculum management. If learners are in school environment, they follow the curriculum for courses in their level, and grade. The **Instructor** supports learners during learning process. The Instructor needs to create course instances (courses customized according to specific educational needs), and to define and tune course instance environment.

For course production process, there are course consultant, course author, lesson author, learning object author, and media author. The **Course Consultant** is responsible for mastering whole course production process by: preparing the course scenario according to standards;

coordinating with authors; and specifying the environment required to run the course. **Authoring Actors (Course, Lesson, Learning Object, Media, and Assessment)** are responsible for creating and modifying sharable and independent units (course, lesson, learning object, media, or assessment) according to the requirements of the course consultant to fit with the course scenario needs, or prepare general purpose units to enrich the system repositories.

For administration process, the **System Administrator** takes full control over the system, manages system resources such as users' accounts and groups of users, assigns permissions, and defines settings for the system. He/she also monitors event logs and maintains the system in secure and stable state. Also, the **Course Administrator** to manage master courses, course instances and curriculum. A main course folder contains all the related files to the course. Course instances are copied based on the main course but fit with the needs of each individual section needs. We mean by curriculum a cross table for course instances, student groups and instructors. The **Copyright Manger** manages the copyrights and payments if exists during importing or exporting of the system materials and modules with the outside world. Finally, the **Interoperability Manger** manages the interoperability between the system and other related systems. It acts as a broker to facilitate the operations between the system and outside world

An **Unregistered User** can easily browse information about courses taught within the system. Also he can access a sample course, and can take part in the discussion forums of different courses. This follows the "knowledge-access for all" philosophy by allowing the permission to obtain the knowledge of his/her subject of interest.

5. WLEA Logical View

The logical view of the WLEA is shown in Fig. 3 to simplify the understanding of the WLEA. The logical view is divided into logical layers: media layer; data layer; learning layer; common layer; and presentation layer.
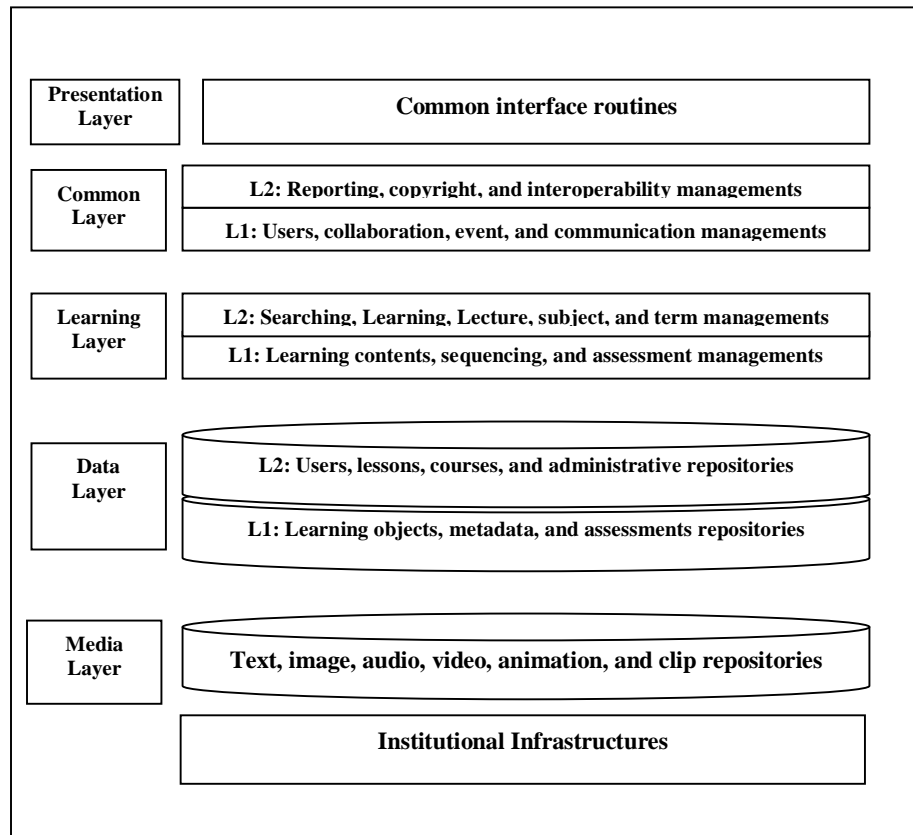
Fig. 3. The logical view of the AWEL

The **presentation layer** presents the contents in an acceptable way for the user, and presents the tracking information about the users' activities. **Presentation of contents** enables the delivery of contents using: dedicated points (e.g. a portal); or wireless terminals; or simply through traditional terminals and browsers. **User/activity tracking and monitoring** philosophy-standard enables tracing actors' interaction with the system, and giving statistics about the performance which are basis for adaptation and modification of the system.

The **common layer** contains the software modules related to the general part in the e-learning system as any other software system. This layer is divided into two levels: level 1, and level 2. Level 1 represents the essential part of that layer to fulfill the common application needs. It includes users, collaboration, event, and communication management

modules. Level 2 represents the supplementary part for that layer to enable the e-learning system to interact with other systems in the learning community. It includes reporting, copyright, and interoperability management modules.

The **learning layer** contains all the software modules related to the educational process. This layer is also divided into two levels: level 1 and level 2. Level 1 represents the principal part in the layer to fulfill the minimum educational process needs. It includes learning contents, sequencing, and assessment management modules. The second level represents the complementary part for to support a complete educational process. It includes searching, learning, lecture, subject, and term management modules.

The **data layer (resources)** contains metadata and scenario repositories about: courses, lessons; learning objects; and tests and quizzes, also it includes also information about users. This layer is divided into two levels; leve1, and level 2. Level 1 includes learning objects, metadata, and assessments repositories, whereas level 2 includes users, lessons, courses, and administrative repositories.

The **media layer** includes any kind of media. The media in that layer can be imported from existing resources or it can be produced by organization media editors (graphics editor, audio editor, and video editor). This media should follow a naming standard to be easy for users to browse and use. This layer is separated from the data layer to enable reusability at the lowest granularity level of a clip, image, audio, or video, and also, to enable reusability of this media with different learning objects in different courses.

6. WLEA Physical View

This section describes the packages within WLEA main subsystems: learning content management subsystem, learning management subsystem, management subsystem, and community subsystem. For detailed description of these packages activities, please refer to Appendix B.

6.1 Learning Content Management Subsystem

The Learning Content Management Subsystem (LCMS) includes all packages related to produce master copies of all courses used in the system. It includes packages for master course: preparing; authoring; and packaging (assembling/sequencing). For example, in physics we may find a course PHY 101, distributed through five sections SA, SB, SC, SD, and SE. The master copy of the course material is prepared in LCMS and an instance for each section will be produced in LMS. This ensures that the system has only one master copy stored in course master copies database, and many instances that can be tuned according to each section needs. **It includes also** *(Course, Lesson, Learning object, Media, Assessment) Authoring Management to* manage authoring process such as: creation; modification; updating; naming; importing; exporting; or migrating legacy sources.

In **LCMS** master copies of all courses used in the system are prepared. Course scenario is prepared according to pedagogical, managing, and technological course requirements. As shown in Fig. 4, each author tries to bring the required material in his/her level by browsing the available repositories, or querying the related e-learning repositories. If s/he found the material, s/he can upload it or s/he would make a scenario by dividing the required unit (course, lesson, and learning object) into the next lower level of granularity (lesson, learning object, and media). Then, s/he coordinates with the next level author to get these units. Finally, s/he writes the procedure to connect these units together to fulfill the required unit packaging. For example, course author implements the course scenario by communicating with the lesson author to fulfill the course requirements by dividing the course into lessons and so on.

6.2 Learning Management Subsystem

The Learning Management Subsystem **(LMS)** includes all packages related to the learning process from the instructor to the learner in a specific class. Figure 5 shows the LMS packages where the course administrator is involved in the administrative coordination. These packages include: instance course administration; instance course communication; instructor tools; learner tools; and assessment and evaluation.
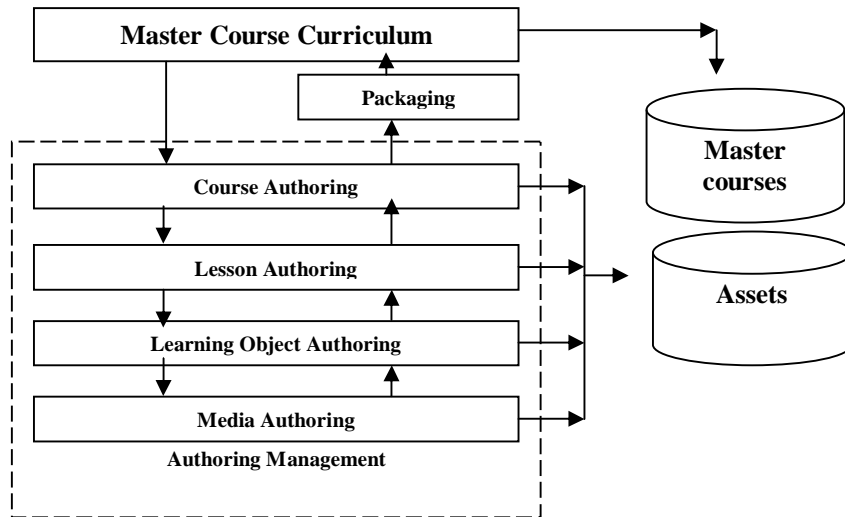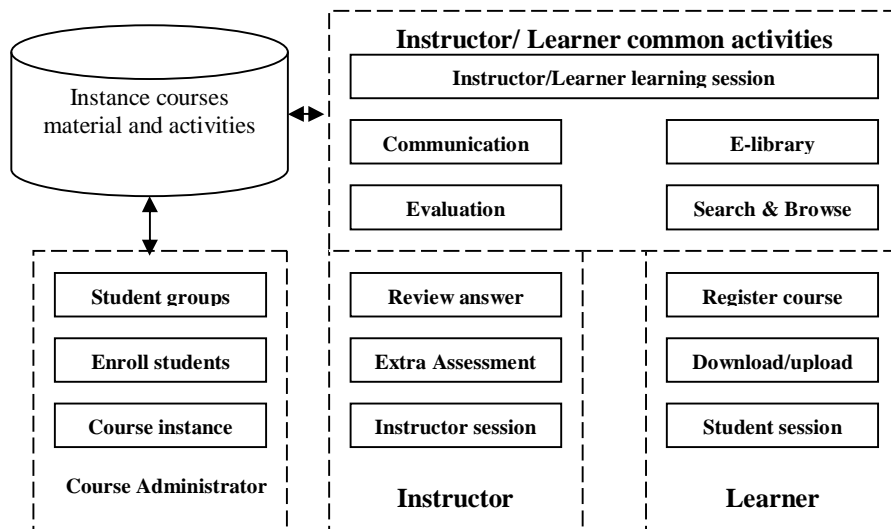
Fig. 4. Learning Content Management Subsystem.

Fig. 5. Learning Management Subsystem

6.3 Management Subsystem

The Management Subsystem **(MS)** includes all packages related to the general system administration tools. As shown in Fig. 6, the MS involves packages for: users' general management; events general

management; reporting general management; general querying and mining; general communication; and general help.

Querying & Mining management package is responsible for the management of understanding queries, mining student answers. *Help and reporting management* package is responsible for giving help at any level within the system.
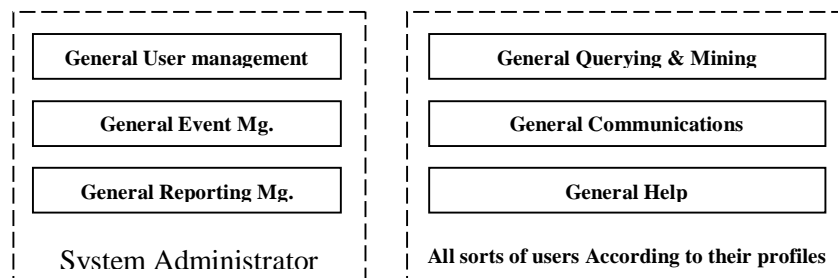

General User management		General Querying & Mining
General Event Mg.		General Communications
General Reporting Mg.		General Help
System Administrator		All sorts of users According to their profiles

Fig. 6. Management Subsystem.

6.4 Community Subsystem

The Community Subsystem **(CS)** includes all packages related to the system interaction with other systems either by importing or exporting activities. Fig. 7 shows the CS packages that include: interoperability management; and copyright management. Also, *Interoperability Management* package is used to support interoperability between the system and other systems for import/export operations. Finally, *Copyright management (Digital Rights Management)* package is used by copyright manager, or software agents to handle copyright, and payment issues, when the system interacts with other systems. This includes: import payment; export fee; and export copyright.
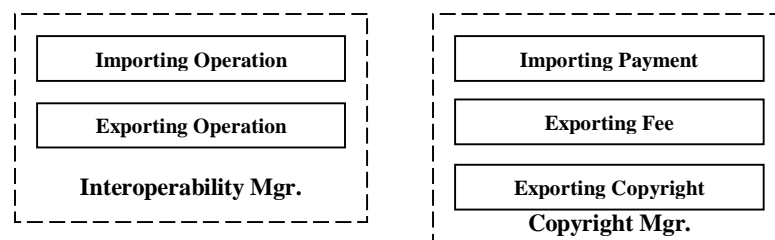

Importing Operation		Importing Payment
Exporting Operation		Exporting Fee
Interoperability Mgr.		Exporting Copyright
		Copyright Mgr.

Fig. 7. Community Subsystem.

7. Conclusion and Future Work

Building a qualified learning system requires a complicated set of activities. The WLEA system is proposed to define the different necessary layers for a platform independent framework to support material interoperability, software reusability, and system scalability. It includes authoring tools for course, lesson, learning object, different media types. Synchronous services (chat, online discussions), and asynchronous communications (discussion forums, messages, queries….) are included. The Architecture allows the existence of different user levels according to their roles. The learning environment also supports different educational scenarios for virtual classroom, as well as collaborative learning.

Future work includes the detailed design of the WLEA that matches with the mentioned requirements. Customizing a WELA with specific enterprise needs is one of the future directions. Also, handing the problem of heterogeneous reuse technologies such as component, agent, and services will be one of the most challenging problems.

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Appendix A

Table A1: Detailed Description of WLEA Actors and their Roles.

Actor	Intended Roles
Learners	ù Search and browse announced courses and get general information about these courses; ù Register in announced courses, and receive a notification for registration; ù Browse course material for all courses which he/she is enrolled in; ù Download/upload materials from/to the shared workspace associated with the course; ù Interact with other participants through the communication facilities defined for the course; ù Participate in evaluation process: for example by filling questionnaires; ù Receive information about his/her performance; ù Post queries and questions to the instructor; ù Browse the e-library, either for the course or general e-library; ù Attend online sessions, or in class courses.
Instructors	ù Define the navigation strategy for the course by using tools provided by the system; ù Choose a template for a visual course instance representation; ù Describe the set of communication facilities available in the course instance; ù Define the course instance schedule; ù Set up the evaluation procedures; ù Create and add assessment objects that are not included in the initial course description; ù Review the student submitted answers; ù Record and issue evaluation results, and final grades for the students; ù Generate statistics for students progress; ù Exchange messages with other course participants; ù Answer student queries and questions; ù Export the materials submitted by the students in format, which allows their usage outside the system.
Course Consultants	ù Create and modify a course scenario according to existing standards; ù Create and modify a course meta-data record according to existing standards; ù Describe the (course or customized course) structure and the way to present material to the learner;
Course Author(s)	ù Provide course material by uploading resources; ù Collect course material by browsing the web or any other connecting environment and downloading resources; ù Assemble the different course material according to given scenario; ù Migrate legacy courses material; ù Export the course in a suitable format such as HTML in order to be used outside the system.
Units Authors (Course, Lesson, Learning object, Media, Assessment)	ù Create and modify a unit files according to existing standards that match with course requirements; ù Prepare the attached metadata documents for browsing, exporting facilities; ù Prepare the unit in several: natural languages; learning styles; and learning environments, if needed; ù Name the unit with expressive names (metadata) for query in later

	ü	stages;
	ü	Provide the unit to the system by uploading media resources;
	ü	Export unit to the system by downloading resources;
	ü	Migrate legacy document files to fit with the system;
	ü	Prepare the help information related to learning objects, how to use…etc.
Course Administrators	ü	Register courses and course instances;
	ü	Delete courses and course instances from the system;
	ü	Define access mode for a course instance as open or limited (a fee is required);
	ü	Enroll students and groups of students in a course instance;
	ü	Remove students and groups from a course instance;
	ü	Create and manage the curriculum;
	ü	Manage student groups and assigning a course instructor to each group;
	ü	Send messages to other users via the internal mail.
Copyright Manager(s)	ü	Verify requested material of other systems to be copyrighted and handle payments if needed;
	ü	Broker with other systems about their material copyrights, and payment method if needed;
	ü	Verify (authorize) the requests of different authors (course, lesson, learning object, media, or assessment) to request certain material from other systems.
System Administrators	ü	Add and modify personal data and delete users;
	ü	Create, edit and delete groups of users;
	ü	Assign permissions to users and group of users for every object in the system (e.g. course, course instance, tests, shared/personal space, chat, discussion board, etc.);
	ü	Manage event log files, determine which events to be logged, view and delete event logs;
	ü	Send messages to other users via the internal mail.
Interoperability Mangers	ü	Verify requests from users to import certain material from other systems;
	ü	Verify requests from other systems to interoperate with WLEA, check and validate their requests;
	ü	Connect with learning search engines to check if the requested units are there or not;
	ü	Support the learning search engines with the requested information about stored media in the repositories.

Appendix B

Table A2: Detailed Description of WLEA Packages' Roles.

Package	Intended Activities
Master courses Management	ü Create and modify a course scenario; ü Create and modify a course meta-data; ü Describe the course structure; ü Describe the personalized course structure.
Authoring Management (Course, Lesson, Learning object, Media, Assessment)	ü Create, modify, upload, and download unit material; ü Prepare the attached metadata; ü Prepare the unit in several: natural languages; learning styles; and several learning environments, if needed; ü Name with expressive names (metadata); ü Migrate legacy documents; ü Give related help information.
Instance courses Administrations	ü Managing courses instances; ü Assigning students to student groups; ü Enroll students.
Instance course communications	ü Chat, virtual chat rooms; ü Discussion board within the same course, or different courses; ü Support news (general news, or personalized news), and e-mail services; ü Control shared/personal space: for each course; for each user; or for each group).
Users Management	ü Manage users; ü Add, delete, and update user information; ü Manage user groups with certain system activities; ü Add, delete, and update group information; ü Assign user permissions.
Event Management	ü Manage system event logs and so on; ü Add, delete, and update an event; ü Update event permissions.
General communications management	ü Chat , virtual chat rooms; ü Discussion Board for general topics; ü News (general news, or personalized news), and E-mail services.
Querying & Mining management	ü Understand student queries and external queries to the system; ü Analyze student answers.

نظام لبيئة تعليمية مبنية على الويب

مصطفى السيد صالح و أحمد عز الدين عواض

قسم علوم الحاسبات - كلية الحاسبات وتقنية المعلومات
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المستخلص. يمثل التعليم الإلكترونى توجها جديدا فى المؤسسات التعليمية والتربوية. ومن المعالم الأساسية فيه هو التفاعل بين المعلم والطلاب باستخدام الوسائل الإكترونية، وجلب المادة العلمية للمتعلم على أساس خصائصه الذاتية ومهاراته. ويقدم هذا البحث نظاما لبيئة تعليمية على الويب WLEA والذى يهدف لتعريف الطبقات المختلفة بإطار عام لا يرتبط بنظام حاسوبى معين ويدعم خصائص تبادل المادة العلمية وإعادة استخدام البرمجيات وتنامى النظام. ويحتوى WLEA على أدوات تأليف للمادة العلمية على مستويات مختلفة مثل المنهج والدرس والكائن التعليمى والوسائط. كما يشتمل على خدمات متزامنه مثل الدردشة والنقاشات المباشرة. كما يدعم الخدمات الغير متزامنه مثل منتديات الحوار والرسائل والاستفسارات. ويشمل هذا النظام أيضا سيناريوهات مختلفة للتعليم والتى تصلح لأنواع مختلفة من التعليم الإكترونى والمبنى على الويب مثل الفصل الافتراضى والتعليم التشاركى.