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Engineering of E-Learning Content Creation: Case Study for African Countries

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***Abstract*—**This research addresses the use of an e-Learning creation methodology for learning objects. Throughout the process, indicators are being gathered, to determine if it responds to the main objectives of an engineering discipline. These parameters will also indicate if it is necessary to review the creation cycle and readjust any phase. Within the project developed for this study, apart from the use of structured methods, there has been a central objective: the establishment of a learning atmosphere. A place where all the professionals involved are able to collaborate, plan, solve problems and determine guides to follow in order to develop creative and innovative solutions. It has been outlined as a blended learning program with an assessment plan that proposes face to face lessons, coaching, collaboration, multimedia and web based learning objects as well as support resources. The project has been drawn as a long term task, the pilot teaching actions designed provide the preliminary results object of study. This methodology is been used in the creation of learning content for the African countries of Senegal, Mauritania and Cape Verde. It has been developed within the framework of the MACbioIDi, an Interreg European project for the International cooperation and development. The educational area of this project is focused in the training and advice of professionals of the medicine as well as engineers in the use of applications of medical imaging technology, specifically the 3DSlicer application and the Open Anatomy Browser.

***Keywords*—**Teaching contents engineering, e-learning, blended learning, international cooperation, 3DSlicer, open anatomy browser.

I. Introduction

It has always been common to many teachers to create their own learning materials: tutorials, books, exercises, web pages, blogs, animations, training videos or even software applications [1]. Over the past two decades a wide variety of these materials have been created using new technologies and delivered through internet. The process should be structured, planned and developed according to the most appropriate criteria in the selection of tools, contents –theoretical and activities-, timing, features and objectives, leading us to increase the quality of learning [2], [3]. Although it seems trivial, following a methodology is being widely accepted by the academic community. The use of a methodological approach has identified different reasons to its use:

- The planning process of the different phases allows the use of the resources, human and material, properly.
- The phases followed improve the quality of the material created, because the reviews are an essential part of the process and are made by multidisciplinary teams.
- Depending on the nature of the learning objects, thinking about the creation process facilitates the high quality of these learning elements as well as their reuse.
- The creation of learning objects that can be tagged means a step further regarding the creation of repositories that can be used to personalize new training programs.

These key elements have been decisive in order to tackle the training program studied in this work, not only because the efficient use of the resources is important in the creation of learning objects, but also because of their particular nature.

This training program is addressed to clinicians and engineers from the countries of Senegal, Mauritania and Cape Verde. Medical imaging technology has become an indispensable tool in many branches of the biomedical, the health area and the research, and is essential the training of professionals in these fields [4]. Besides, awareness of linguistic diversity is advancing, and high levels of international and governmental organisations are operating in an ethics of protection and of solidarity in regard to subordinate linguistic and, above all, economically less developed groups [5]. Due to the importance that many African countries give to the concept of linguistic sustainability, and considering that it has been developed within the framework of an INTERREG project, for this program, learning objects and lessons have been created in different languages. It has been outlined as a blended learning program with an assessment plan that proposes face to face lessons, coaching, collaboration, multimedia and web based learning objects as well as support resources.

Alongside the development of this training program, this paper aims:

(a) To study the process of design and construction of learning objects, using a methodological approach.
(b) To gather all the necessary information to analyze and study the results of the application of a methodological approach to a multilingual training program directed towards a multidisciplinary group of African professionals in the field of medical technology.

II. Engineering Methodologies and Learning Objects

There have been several attempts to use a methodological approach in the creation of teaching contents, from the use of very simple agendas or planning, to detailed studies to a greater or lesser extent. In the literature it is possible to find

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research works that propose methodological approaches, technological frameworks, or both, aimed to pedagogic models. Fidalgo-Blanco [6] proposes both elements to improve learning outcomes in MOOC's. Some of these works make use of software engineering methodologies, Wai [7] proposes the *Agile Teaching/Learning Methodology*, designed for higher-education, based on the best practices and ideas from the field of software engineering and leveraging upon concepts from agile software methodologies. Other works make use of educational systems evaluation, Lanzilotti, in her work [8], discussed the concept of the quality of e-learning systems. Some studies such as Methodological approaches in MOOC research: *Retracing the myth of Proteus* [9] explores the methodological approaches most commonly adopted in the scholarly literature on Massive Open Online Courses (MOOCs). More recently Prieto de Lope introduces the *Design methodology for educational games based on interactive screenplays* [10], and *Designing educational games: key elements and methodological approach* [11]. In the first one, based on game development methodologies, the proposal seeks a balance between the overall and the detailed view required to create the game. In the second one, the proposed methodology focuses on the design phase of educational games. Also Saldaña Hernández in her work *MOAM: A methodology for developing mobile learning objects (MLOs)* [12], proposes a methodology composed of five phases, to develop high quality MLOs. There are also some proposals about the use of a methodological approach similar to those used in the engineering field that are aimed to some specific learning objects, such as training videos (in their different formats) or interactive software applications [13], [14].

There exist many definitions of learning objects:

- Any entity, digital or non-digital, that may be used for learning, education or training [15]
- Any digital resource that can be reuse to support learning [16]
- Modular digital resources, uniquely identified and meta-tagged that can be used to support learning [17]

And although there exist more definitions in the literature, all of them have something in common: Learning objects are a piece of learning material used in the educative context. It is possible to find many other terms tied to its definition: training components, information pills, knowledge bits, learning components, learning contents or learning containers among others. The literature also exposes the different features that characterize them:

- Discoverability, since they are described by the Learning Object Metadata (LOM), formalized as IEEE 1484.12. [18] It means to what extent it is easy to find a piece of information in an information system or database.
- Reusability, supported by the IMS consortium, using specifications such as the IMS content package [19]. It means for a learning resource its reuse in practice, a learning object may be used in multiple contexts for multiple purposes.
- Interoperability, by the sharable content object reference model (SCORM) [20], a collection of standards and specifications for e-learning. It means the possibility of exchange and use the information exchanged by working with open standards between two or more systems.

A significant aspect of learning objects composition is the Learning Design Specification (LD). IMS-LD is a metalanguage specification that enables to model learning processes. The IMS-LD supports different pedagogical approaches such as active learning, collaborative learning, adaptive learning, and competency-based learning [21]. LD is defined as: The description of the teaching-learning process, which follows a specific pedagogical strategy or practice that takes place in a unit of learning towards addressing specific learning objectives, for a specific target group in a specific context or subject domain [22].

This research work is focused in the following characteristics:

- Modularity, composed of independent pieces that interact with each other.
- Portability, they are independent from the runtime environment used.
- Scalability, all of them are thought to be used in the future and maybe in a different scale.
- Extensibility, considering that their amplitude could be increased, allowing the easy incorporation of new elements such as, for example, resolution methods.

Besides these characteristics, it has been considered two more of those proposed by Beck [23], adapted from the Wisconsin Online Resource Center (WORC), as key characteristics:

- They can be aggregated, grouped into larger collections of contents, including traditional course structures.
- They are tagged with metadata, defined with descriptive information allowing it to be easily found by a search.

These learning objects are the central piece of the training program proposed, where the focus is on the methodology used to develop them. Currently it is quite common to reuse and share these resources throughout internet. The leading Open Educational Resources (OER) movement and other international initiatives have highlighted the importance of sharing and reusing LOs among teaching communities [24].

Learning Objects Repositories (LOR) are then used to store LO and their metadata. The IEEE LOM standard is proposed for metadata management, this divides its elements in nine categories: general, life cycle, metadata, technique, education, rights, relationships, annotation and classification [25]. Fig. 1 shows the data model LOM, from which only a group of categories is used in the graphical elements used in our proposal.

III. Methodology to Develop Learning Objects

The present work has been developed within the framework of the MACbioIDi, an international cooperation project funded by Interreg. The training program case study has been developed for medical and engineering professionals whose main objectives are on the one hand training in technologies of medical image computing and on the other hand the creation

of a professional hub in which to develop future training and research activities. These professionals come from the countries of Cape Verde, Mauritania and Senegal and also involved in the project are the ultra-peripheral European regions that belong to the Macaronesia: Canary Islands, Azores and Madeira [4].

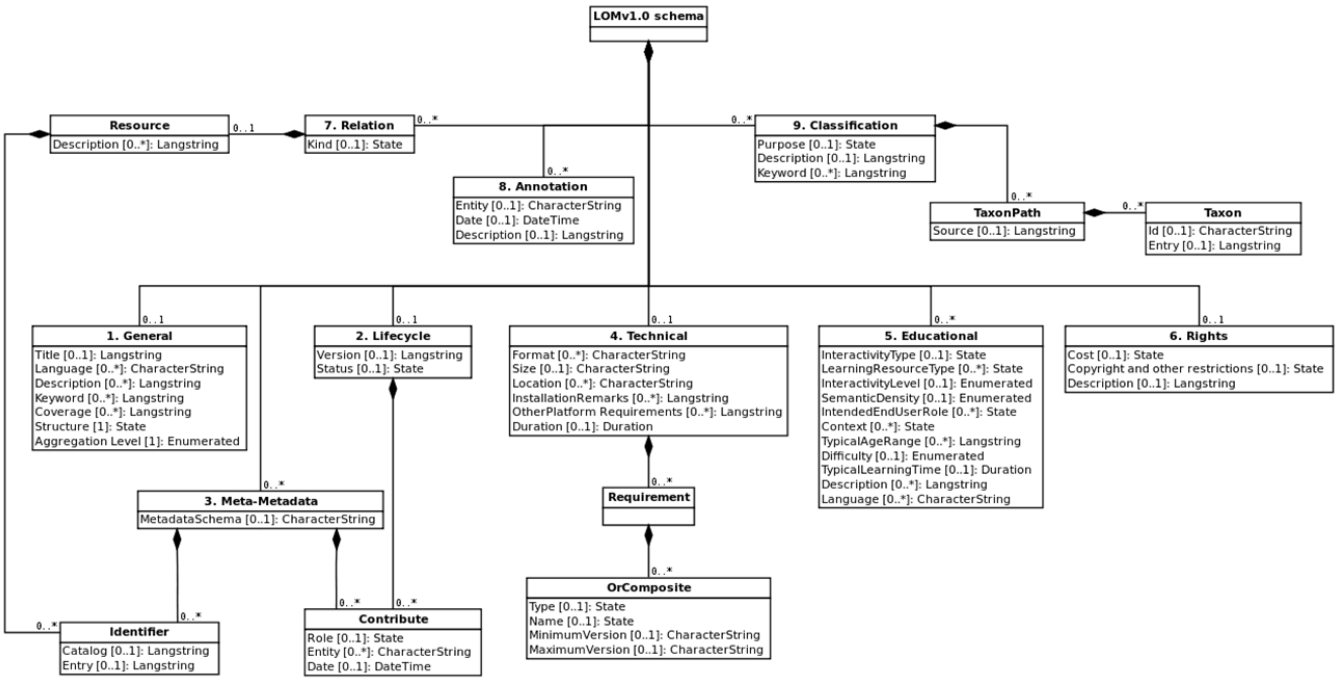

Fig. 1 Schematic representation of the hierarchy of elements in the LOM data model LOM

The contents of this training program are about the Open Anatomy and 3Dslicer applications and the ecosystem around them: programming languages, integrated development environments, libraries and additional software to install and develop future modules. The Open Anatomy browser is an anatomical atlas, accessible from the web, which presents an interactive map of the human body [26]. The 3D Slicer is an application for medical image informatics, image processing, and three-dimensional visualization [27]. Bearing in mind that the 3D Slicer application is been developed and used by a broad international community of professionals, one of the main objectives of this work is to study and establish a methodology with which to create educational material. This material comes from both the large number of tutorials [28] with which the 3D Slicer currently counts and new learning objects that will be developed within the project. They will be characterized by being multilingual and being part of a repository to configure future courses for different professional profiles and for different learning levels.

The methodology proposed for the creation of these learning objects divides the process in five phases: Analysis, design, development, test and delivery. Although at some point a review of a phase could mean to go back to make any change, each phase output is used as the input of the next one. Fig. 2 shows a canvas used during these phases for both teachers and developers to have a general idea about the process. This canvas is similar to the graphic information used in the scrum methodology.

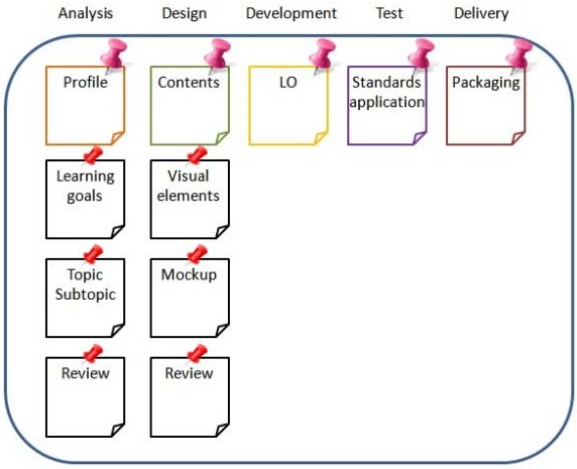

Fig. 2 Learning Object canvas

The information from LOM to be displayed in the canvas comes from the categories (numbered as in Fig. 1):

- General. (See 1 in Fig. 1). General information that describes the learning object as a whole.
- Technical (See 4 in Fig. 1). Information about the technical requirements and technical characteristics of learning.
- Educational (See 5 in Fig. 1). Information about the pedagogical and educational characteristics of the learning object.

With this information, the documentation of the phases is

reduced to what is needed before the packaging of the delivery phase.

A. Analysis

During this first phase, the requirements needed to the learning object design are determined throughout the setup of the elements in the detailed stages:

1) Stage 1. The student's profile. For this training program clinicians and engineers in the field of biomedical research have been considered. The students' profile is the key characteristic for many other elements to be established.
2) Stage 2. The learning goals: objectives and competences. In this stage, a studied description of the skills and abilities the students must accomplished is established.
3) Stage 3. The topic and subtopic of the learning object, including the selection of the content to be taught. In this stage the definition of the format; text, audio, video, animation or software application with information about the size, extension and description is required. It is also important to include information about the type of lesson and language/s used.
4) Stage 4. It is important to review the stages 1-3, since terms and concepts must be clear and properly used.

In addition to the LO Canvas, tables can be used to document some of the stages (see Tables I, II).

TABLE I
LO EDUCATIONAL LEVEL

Level	
Basic	□
Medium-low	□
Medium-high	□
High	□

TABLE II
LO FORMAT

Level		
Text	□	Extension
Audio	□	Size
Video	□	Description
Animation	□	
Software Application	□	

B. Design

During this second phase, the information gathered during the analysis is used to draw a graphical representation of the object. The W3C Standard best practices for web design and applications [29] have been used. It is addressed to build and render web pages and a set of technologies for web applications as well as the web content accessibility guidelines [30].

1) Stage 1. The contents are structured and organized, depending on the format: An index for the text format, a screenplay for audio, and a story board for the training videos and animations. Finally in the case of software applications, UML diagrams will be used [12]. The structure must represent the way these contents will be displayed and help in the understanding of the different levels.
2) Stage 2. All the visual elements are drawn. When the learning objects are created for a specific program it is recommended to use a general format: Headers, footers, logos, shapes, size, colors, or fonts among other graphic elements. The computer-human interaction must also be described with graphical elements, such as menus, buttons, text boxes or drop-down lists among others, as well as the layout. All these elements must offer an intuitive interaction
3) Stage 3. A mockup must be implemented to get a better idea of how all the elements described fit together. If for some reason a prototype is needed it is possible to add some functionality to be tested.
4) Stage 4. In this review stage the mockup or the prototype is contrasted with the analysis made in the previous phase to verify the accomplishment.

C. Development

Depending on the format there will be different paths to follow in this phase:

- Text format: It is important the text edition with the correct structure, information and other elements such as images, glossary or bibliography.
- Podcast: The screenplay will be used in the recording sessions needed, after this in a post-production process; the raw material is transformed and corrected in order to create the learning object. It is important to learn basic notions of speech, voice management and reading practice in front of the microphone.
- Training videos: The story board is the central piece from which to start; it is used for the recording sessions where, besides the basics about the speech it is also needed to learn basic notions of discourse, voice management and behavior practice in front of the camera.
- Animations: Starting from the storyboard, layouts, model sheets, and animatics, the animation is created; finally compositing and edition will be needed to create the learning object.
- Software applications: The agile methodology scrum [31] has been used. Using the information in the UML designs the learning objects are developed and tested.

These are the steps followed in this program, eventually these steps may change according to the resources, professional profiles in the creation processes, agenda or contents, this way each program may draw its own pipeline determined by these key elements.

D. Test

It is essential to validate that the learning object accomplishes the initial requirements. For the technical aspect, the IEEE Standard for System and Software Verification and Validation [32] has been used to determine whether the development conforms to the requirements. The scope encompasses systems, software, and hardware, and it includes their interfaces. This standard applies to systems, software, and hardware being developed, maintained, or reused. It also

includes the analysis, evaluation, review, inspection, assessment, and testing of products. For the learning aspect, besides the metadata and packaging from the delivery stage, there are elements that have been taken into account: Contents appropriateness, learning goals achievement, suitability of examples, number and level of activities, and explanation of contents.

E. Delivery

This last stage implies to put at disposal of users the learning objects created. For the learning object packaging SCORM [19] is used. For this training program, learning objects packaging will be delivered by the LMS moodle since it has been used in the ULPGC for several years now and after been installed and tested in the servers of the MACbioIDi project is the chosen one. It offers all the features needed for this and future programs within the project, due to its flexibility, standard modules offered and the big community support [33].

Although these phases are the core of the work, it is important to not forget that the definition of the whole training program, in general terms, profiles, timing, objectives, has been the fundamental pieces of the whole project.

IV. Conclusions and Future Lines

Learning objects are an effective way to develop training contents. Due to their different formats: tutorials, books, exercises, web pages, blogs, animations, training videos or even software applications, sometimes it is needed a multidisciplinary team for their design, development and tests. Different professional profiles such as experts in the contents, in writing, translators, designers, software engineers or developers should be involved in the processes. This model contributes to the creation of knowledge for learning objects that, increasingly, adapt to emerging technologies.

The standardization offered by the LOM, and how to address the different phases proposed in this work for their development makes it necessary to use a methodology with a cooperative model of development to create the learning objects and prepare them to be part of repositories. Within this methodological approach, suggestions, advices, tools, standards and best practices that assist each stage activities have been also expose7d.

The *Lompad* editor [34], a meta-tagging tool for learning objects, has been used. It supports the *IEEE-lom specification* and SCORM profile, the standards used in this work.

The preliminary results and indicators gathered, from the adaptation or development of learning objects of each type show that this methodology facilitates the interaction and work in a multidisciplinary team of professionals.

For future training programs and the creation of new learning objects, it is planned to include in the design of these training elements the learning style of the students, based on a previous study of methodologies and/or tests for their definition and classification.

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