

Some Research Questions and Results of UC3M in the eMadrid Excellence Network

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Abstract— Universidad Carlos III de Madrid is one of the six main participating institutions in the eMadrid excellence network [73], as well as its coordinating partner. In this paper, the network is presented together with some of the main research lines carried out by UC3M. The remaining papers in this session present the work carried out by the other five universities in the consortium.

Keywords- *e-learning, technology enhanced learning*

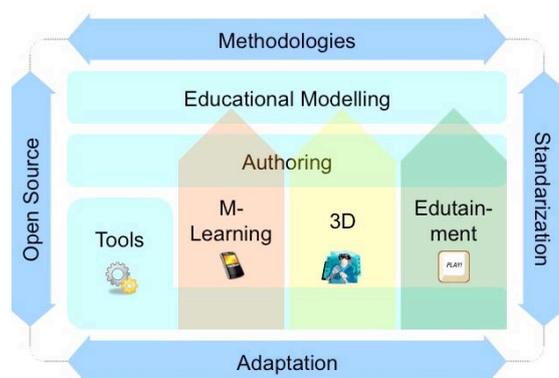
I. INTRODUCTION

eMadrid [73] is the name of the Excellence Network about e-learning funded by the Regional Government of Madrid. Its members are the Universidad Carlos III de Madrid (UC3M), who acts as a coordinator, Universidad Autónoma de Madrid (UAM), Universidad Complutense de Madrid (UCM), Universidad Politécnica de Madrid (UPM), Universidad Rey Juan Carlos (URJC) and Universidad Nacional de Educación a Distancia (UNED), together with a large number of associated companies and educational institutions. The aim of the network is to provide leadership and perform advanced research in the area of e-learning.

Much progress has been made in recent years in the field of e-learning, but important challenges lie ahead for this technology to maximize its impact. Questions such as the following are of great interest for the future: What authoring tools may be provided so that creating educational material is as smooth and simple as possible, so that authoring can be incorporated into the educational process by all agents involved in it, including the students themselves? What impact do recent advances in web technology, such as the web 2.0 and semantic web technologies, have on education? How can the open source approach boost learning management systems? What new teaching models and methodologies can be supported by educational tools? What role does standardization play for e-learning formats and tools and how it can advance the state of the art? How can the integration of games, that are having such a success among the young, impact learning? How can we support formal and informal learning with the use of mobile devices, which are in the pockets of almost everyone?

Although the research to be carried out is intertwined and related, the consortium has organized its work around the following research lines: (1) Educational modelling (including collaboration & virtual communities), (2) Educational methodologies based on ICT, (3) Standardization of tools and educational content, (4) Platforms and tools for e-learning, (5) Adap-

tation, adaptability, and accessibility, (6) Immersive 3D learning, (7) Edutainment (Integration of games and simulations in Virtual Learning Environments), (8) M-learning (Mobile and ubiquitous learning), (9) Authoring & Applications of Web 2.0 and Web 3.0 to e-Learning, and (10) Free and Open Source Software. This figure shows the relationship among them:



We distinguish 3 main phases in the educational process: the phase of educational modelling, where the learning process is planned, the authoring of the needed learning material and assessment, and finally the tool-based deployment and enactment. For each of these main phases, we have one research line. But apart from the mainstream application areas, there are 3 promising areas, which deserve particular attention. These are m-learning, 3D virtual worlds, and game-oriented learning, which cut across the main areas. Due to their future importance, we study them in detail in independent research lines.

All this is framed by educational methodologies (giving a pedagogical underpinning to the learning process), standards (enabling interoperability among tools), adaptation in the most general sense (to classes of users and their abilities and context), and development principles (among which we concentrate on open source).

This paper is the first in a special session about the eMadrid excellence network. The remaining 5 papers by the other consortium partners touch upon several of the research lines mentioned. The paper by UCM describes their approach to introduce educational games in the learning flow. URJC presents the influence of libre software in education on the basis of a case study. Apart from open source programs, open educational resources are acquiring increasing importance. The paper by UPM covers a proposal for the use of semantic web techniques for making their discovery more effective. UAM

describes how virtual 3D technologies can be used for learning. UNED's paper proposes a new paradigm for authoring that takes advantage of semantic web techniques.

The Universidad Carlos III de Madrid participates in all 10 research lines identified for the network, but, for the purpose of this paper, we will have sections about all the topics except two: the one on edutainment (we will make some reference to it in the section about 3D worlds) and the one on open source software, although most of the developments carried out are open source software. We will refer to them in several sections, most notably in the one about frameworks and tools.

II. EDUCATIONAL MODELLING

Learning scripts are external representations of the procedures and relations among participants and elements in a learning flow. Based on instructional design techniques to translate pedagogical models into a structured plan of activities and materials, scripted courses help students to focus their attention on relevant resources and activities [1]. There are several formats to deliver structured learning flows, ranging from pure text based instructions to graphics and diagrams of activities. Even if the structure is the same, different delivery methods may affect students' performance on the course.

On the way to capture all the richness of human interactions into a learning design, authoring tools promote Domain Specific Languages [2] such as IMS Learning Design [3], LDL or LAMS. The use of modelling languages implicitly imposes three phases in the course life-cycle: authoring, deployment, and enactment. For authoring, modelling languages allow instructors to define all interactions and resources in the course in a computer-readable way. Deployment is devoted to allocate resources and assign actual course participants to the abstractly defined roles. The course starts at the enactment phase, where instructions given by the script are delivered and interactions among course participants take place.

The number of tools aimed to support the course life-cycle for educational modelling languages designs is increasing rapidly and the market is willing to adopt new techniques of learning delivery. Despite these significant efforts, there still exist open issues in the field, requiring further research to be addressed. Main open questions include usability of the different approaches and its relationship with technology adoption; identification of patterns and its expression in form of scripts; and support of emerging learning techniques related with the wide acceptance and potential of Web 2.0 tools in the field of collaboration and course adaptability.

IMS Learning Design [3] is considered the *de facto* standard for educational modelling. It is intended to support a wide range of pedagogical models. General-purpose authoring tools such as RELOAD, COSMOS or CopperAuthor offer a close-to-specification interface which cannot be used by non-experts in the field. As a result of the difficulties shown during course edition, there is still a low level of adoption of the specification. Current research guidelines promote the inclusion of a new abstraction layer to reduce the gap among the technologies and the practitioners.

A different approach to improve usability of authoring tools and therefore to increase the adoption of IMS Learning Design relies on the identification of patterns of interaction [4]. Patterns are widely accepted in the field of collaborative learning and, in the long term, allow instructors to identify best teaching techniques.

Script-based learning, as well as the whole area of e-learning, has recently received the positive impact of the success of Web 2.0 techniques, whose tools promote participation, interaction, and new forms of communication among users [5]. The inclusion of emerging modes of interaction on educational patterns presents a challenge that can be faced from different perspectives. On the one hand, there is a great potential on the development of new learning strategies that rely on emerging web features. On the other hand, the distributed nature of the web hinders the creation of scripted courses due to the difficulty to express during authoring how course participants will interact with a service, whose nature and usage details would (and will) change on time.

The UC3M group contributes to the adoption of IMS Learning Design with GRAIL, a compliant runtime environment integrated with the .LRN Learning Management System [8]. We considered that the strict division of the course life-cycle of authoring, deployment, and enactment imposes a severe drawback for the adoption of the specification. Current developments are focused on the provision of an authoring-phase functionality once the enactment phase has started. Following the metaphor of a cockpit, the tool incorporates facilities for actions such as editing existing resources, creating new ones, or modifying conditions imposed to the course. Another research line that makes use of GRAIL is focused on service integration within structured scripted learning flows. The UC3M group studies the impact of the inclusion of third party services in the course life-cycle and develops models to perform the actual integration [7]. Software components built on top of GRAIL allow the evaluation of the proposed solution.

III. ICT-BASED EDUCATIONAL METHODOLOGIES

The introduction of Information and Communication Technologies (ICT) in the educational setting opens a wide range of learning possibilities. Flexibility, both regarding temporal as well as spatial constraints, is traditionally awarded as a key advantage of the use of ICT in learning. ICT facilitate the delivery and accessibility of learning resources, the use of richer multimedia and helps fostering collaboration and interaction between students and teachers, as well as between students themselves. Thus, far beyond the direct translation of traditional face-to-face methodologies, ICT bring a rich set of expectations for adapting such methodologies and introducing new ones to motivate the students and improve their learning outcomes.

Learner's assessment is perhaps one of the areas where this combination is proving to turn into a richer symbiosis. ICT strongly facilitate the management of the assessment process, leveraging the teaching burden associated to it. But apart from the logistic support, ICT empower potential benefits of the

assessment process (for example, fostering immediacy of feedback) as well as open new scenarios for student evaluation.

Systems based on multiple-choice questions (MCQ) are the most extended Computer-assisted assessment method. Most Learning Management Systems, such as .LRN [8], Moodle [9], Blackboard [10], etc., include the possibility of writing and taking MCQ tests as part of their functionality. In [11], a thorough analysis of MCQ from a pedagogical assessment standpoint is provided, together with an assessment framework and a set of feedback principles for improving their effectiveness. From a didactic point of view, immediacy is one of the key advantages of MCQ, as automatic feedback can be provided to the learner instantaneously. Such immediacy is considered a critical requirement for successfully supporting the student learning process. Despite of their wide use, MCQ suffer from some limitations as stated in [11] and alternative methodologies can be considered more appropriate depending on the learning outcomes to be assessed.

Web 2.0 applications in learning are based on constructivist theories. Web 2.0 technologies allow the students to actively participate in the learning process, interacting with their peers and the instructor and even collaborating in the generation of learning materials. Moodle is an example of LMS inspired on constructivism. The use of Web 2.0 technologies for assessment focuses typically on the use of blogs [12] [13] and wikis [14] [15], as simple but flexible portfolios, which provide an easy-to-use framework for personal reflection, discussion and collaboration.

Pedagogic theories advocate the active involvement of the student not only in the learning process, but in the assessment activities too [16]. This objective is easier to achieve with ICT, using collaborative tools for discussing and agreeing rubrics and assessment criteria or peer assessment systems for involving the learners as assessors themselves [17].

Finally, existing online video-conference technology allows for the deployment of richer interactions, close to face-to-face ones. Remote presentations and questioning can be easily deployed today with minimum technological infrastructure (a simple webcam and web-based software). Viva exams are an example of a traditional methodology that can be directly translated to the virtual world using this technology. But ICT can also help to overcome traditional disadvantages of viva exams, such as the lack of persistence or the difficulty of applying homogeneous qualification criteria. Regarding the first point, online meetings are easily recorded, allowing the archive of evidences in a similar way to written exams. Such archives can be then used for future review, potential reclamations or simply as a reference for future students. They can also help to improve the quality of the assessment process, providing a set of samples that can be referred to as examples of how a concrete case should be evaluated. This is one of the objectives of the WebCEF project [18], where a showcase of video samples is being built for assessment of English as a second language according to the European CEF competences reference framework.

Lastly, some concerns related to the use of ICT for assessment should not be ignored. Security remains to be an active issue regarding the deployment of e-assessment formally.

Potential risks include impersonation and cheating as major problems. Current solutions are typically based on the existence of a controlled environment for the assessment. Nevertheless, as such a requirement implies face-to-face settings, an intense research activity is going on to alleviate such security issues while maintaining the e-learning facilities and advantages, based on the use of video images, motion control etc.

UC3M is actively exploring new assessment scenarios and methodologies based on the use of ICT, mostly in the context of the iCoper European Best Practices Network. In this sense, we have focused particularly on two main research lines:

The work developed on adaptive peer review methodology [19] addresses the combination of active participation of the student in the assessment process together with adaptation to foster the motivational and pedagogical effectiveness of the task. ICT is here applied both to support the process logistics and, mainly, to perform the adaptation to the students' profiles.

In collaboration with the Knowledge Media Institute (The Open University), the use of online meetings and video-conference for assessment in different domains, courses, levels and countries is being explored at UC3M. The analysed case studies cover a complete set of situations, ranging from formative to summative purposes and from individual to collaborative (team-project) assessment.

IV. LEARNING CONTENT AND TOOLS STANDARDIZATION

Nobody denies the importance, even more the necessity, of the existence of standards to organize any particular technical field to allow the interoperability of tools. Standards make data independent of concrete tools: they unfasten data from tools. The main objectives of standardization can be summarized in the following points:

- Enabling interoperability among platforms
- Protection of investment on content development
- Exchange of content locally and globally

In the context of e-learning content, several standards have been developed in the recent past. IEEE LOM [22] is a standard that specifies the syntax and semantics of Learning Object Metadata, defined as the attributes required to fully/adequately describe a Learning Object. Learning Objects are defined as any entity, digital or non-digital, which can be used, re-used or referenced during technology-supported learning. SCORM [20] is a set of technical specifications for e-learning software products. It tells programmers how to write their code so that it can "play well" with other e-learning software. Specifically, SCORM governs how online learning content and Learning Management Systems (LMSs) communicate with each other. SCORM does *not* speak to instructional designs or any other pedagogical concern, it is purely a content-oriented standard. There is also a large group of specifications from the IMS Global Learning Consortium (IMS GLC) [21]. Some IMS specifications are: Questions and Test Interoperability (QTI) for assessment purposes, Learning Design (LD) concerning the instructional model, Common Cartridge (CC) to package learning contents using Content Packaging (CP), Learning Information Package (LIP) for

learning information and Reusable Definition of Competency or Educational Objective (RDCEO) related to competences. Most of these have not acquired the status of a standard given by a standardisation organization, but in their absence have acquired wide-spread use.

Andrew S. Tanenbaum [24] highlighted the importance of standards in a comical way by saying “the nice thing about standards is that there are so many of them to choose from.” And this is exactly the key to success. Too many standards for the same topic, implies that there is no agreement and therefore the power of standardization is lost again. There have to be as few as possible standards that are as good as possible. But what does “good” mean, from a general point of view? Different users and tool vendors might need quite different applications of the same format. With the aim to fulfil users’ and stakeholder’s requirements, standards tend therefore to become quite extensive and complex. But then we arrive to another problem: since the standards are so complex, only subsets are implemented in tools. And again different subsets of the same standards, means again no standard and no interoperability.

We believe that standards should be designed to be *robust* against subsetting. This has several implications. One is that a particular concept should be expressible in just one possible way using a selected standard. This is why a good conceptual model is essential from the very beginning. Besides, standards should not be considered complete when experts just defined them; they should incorporate some kind of feedback on how implementations are done, adapting them to real market. Adoption of a standard is a social process that should be planned. It is sometimes easier for a specification to achieve successful adoption if it is presented as a set of small related formats, that each solve a concrete specific topic, than a monolithic format that tries to cover a large field.

Nowadays, assessment interoperability is being identified as one of the barriers to overcome to facilitate reusability in e-learning environments. Content reuse has always been identified as one of the big advantages of using standards. Assessment is a special case where content reuse makes even more sense [23]. Another important field of research is competence-based learning. Efforts are being carried out to clarify the link between learning content and competences. From the assessment point of view, ePortfolio is a tool of great interest to represent achieved learning outcomes and the evidences that sustained them.

UC3M is working towards the study of better standards and specifications in the context of the iCoper project [25]. As part of its objectives, iCoper will provide a Reference Model and mechanisms to ensure European-wide user involvement, cooperation, and adoption of standards in the educational framework. To accomplish this goal, the project will systematically analyse the specifications and standards available and in use, to draw conclusions on their validity. In the context of the iCoper project, an effort is under way to detect and solve the QTI interoperability problems by helping to complete the available tools to guarantee a robust exchange of assessment material. Related to assessment interoperability between some LMS (Moodle, .LRN and CLIX), some modules have been developed to enable this interoperability. These

modules support importing and exporting assessment material between LMS and they are implementations of QTI 1.2.1. iCoper also deals with the link between IMS LD Units of Learning (UoL) and learning outcomes (including knowledge, skills, and competence), using HR-XML [26] as basis. On the other hand, the link between assessment and learning outcomes (through evidence records) is being investigated as well.

V. E-LEARNING FRAMEWORKS AND TOOLS

It is well known that e-learning frameworks and tools are a critical asset for entities involved in the fields of learning, education, and training. These applications are of importance not only to bridge the physical gap between distant learners and the teacher, but to improve the learning experience and outcomes by providing support for other needs like collaboration, personalisation, adaptability, and new approaches of interaction with both learners and teachers.

The development of e-learning applications and platforms has been deeply affected by the present relevance of Web 2.0 tools and social networks that provide new ways for learners to collaborate in a more dynamic way. Systems such as LearnLand [27] and SciSpace [28], both based on the social platform Elgg [29], provide a high level of collaboration among the participants of a course through the utilisation of social tools. The provision of adaptation and personalisation form another area of interest in this field; as a proposal, [30] presents a way to personalise a virtual learning environment through the display of indicators within the LMS interface, while [31] describes an approach for providing an adaptive LMSs based on a standardised user model. In addition, another approach observed is to combine the use of more immersive user interfaces in combination with an LMS, an example of this is the Sloodle platform [32].

Current open research problems include the improvement of the level of adaptability of e-Learning platforms in order to enrich the learning experience. Another line of study is the use of non-traditional tools in the field of e-learning [33] that could lead to the interaction with external services, which requires an exchange of data providing the security and privacy that are taken as granted in any learning environment.

The UC3M group works with the .LRN framework, mainly through the provision and current maintenance of the GRAIL package, an IMS Learning Design RTE. Currently, this player is being enhanced with edition functionalities in order to provide flexibility at the deployment phase. Also, the accessibility has been improved. It has become a permanent requirement within its development. The research group has also provided an assessment package compliant with the version 1.2 of the IMS QTI specification; and by taking advantage of this compliance, current developments are taking place in order to provide assessment interoperability between the .LRN and Moodle frameworks.

VI. ADAPTATION, ADAPTABILITY, AND ACCESSIBILITY

Adaptive educational systems [34] in general appear in opposition to the “one-size fits all” paradigm for educational

environments. When a learning experience is deployed, learners may have significantly different experiences depending on a variety of factors. The definition of an ideal adaptive system would be the one that provides to each learner the most appropriate environment. By environment we understand the context, resources, sequencing, evaluation, communication, support, and any other aspect that shapes a learning scenario. But as remarked in [35], adaptive tools have a poor presence in the LMS market mainly due to their lack of integration capabilities. Brusilovsky analyzes this issue in greater depth in [36] and points to the lack of integration as one of the reasons for this situation.

Thus, adaptation in general is a fairly wide and complex area, because it touches on the multiple aspects that affect a learning scenario. The proposed approach to deal with this complexity is to categorize the techniques for adapting a learning experience. The proposed categorization is:

1. Change the resources used in an experience, its order, its shape, delivery method, etc. depending on observations previously obtained from the user. We call this “Adaptive Choreography”. For example, a learning experience may choose to deploy a group discussion or a set of individual exercises as the next activity in the class depending on some observations previously obtained from the experience.
2. Change the appearance of the platform (not the learning resources) to provide a more appropriate environment. In this category we would have techniques applied to change the appearance of a community, the auxiliary menus shown by default, changing the subscription policy in a forum, etc.
3. Adaptation in the context of accessibility. That is, the entire platform needs to change to any disability. For example, offer a larger font for the visually impaired.

The first category is intrinsically related to a learning environment, whereas the last two are generic to web applications. Any web-based application may need to adapt its appearance.

A. Adaptive Choreography

This type of adaptation has received an important push in recent years. The area of Intelligent Tutoring Systems offers a very rich landscape where numerous tools have been proposed. From the very early tools that were stand-alone and highly specialized in a context, today we can see proposals such as “KnowledgeTree” [36], where the emphasis is in integration with current LMSs using a set of “intelligent educational activities” with a distributed connection scheme.

A formal approach to adaptation has been taken by the IMS Learning Design specification [3]. This specification has been conceived as a formal framework to capture the structure and interaction in a learning experience including (a limited but) specific formalism to capture the interaction with services external to a LMS. Using Learning Design a so called “Unit of Learning” can be described including the set of resources that are to be used, the set of roles assigned to the participants in a learning experience (both staff and learners) and the interactions that are supposed to take place.

The specification is divided into three levels. Level A includes the description from a purely structural form of the set of resources needed by the learning experience. A UoL contains a “play”, which is divided into “acts”, and each act contains a set of learning activities. At any point in time, one act is “active”. Level B of the specification is the one directly related to adaptation. A set of properties with different scopes (a role or set of users, a single user or a global property) can be defined and assigned values. Furthermore, a set of if/then/else clauses may be defined to change the appearance, visibility or structure of an activity based on the values of these properties.

Since the publication of its initial version in 2003, there have been several tools that appeared both in the authoring context [37, 38] as well as the execution context [38, 39]. In theory, a UoL captures all the requirements and pedagogical aspects of a learning experience such that it can be reused multiple times in different contexts.

In reality, adaptive learning with Learning Design has been shown to be fairly complex. Although this complexity could be assumed by instructional designers, its adoption threshold is higher than desired for other member of the teaching staff.

B. Adapting the platform appearance

Here we include the adaptation that needs to happen outside the learning resources of the educational experience more related to the platform in which they are hosted. Most of the current LMSs include a customization layer that allows re-arranging the structure of the pages hosting a course to better adapt to the particular needs of a specific audience.

In Moodle [9] or .LRN [8] (to mention just two examples of open-source LMSs), the community page hosting a course offers a customization menu where the structure of the portlets can be re-arranged. This functionality is included in virtually any LMS. The importance of this adaptation is specially needed when deploying learning experiences with an audience with small experience in the use of LMSs or computers.

C. Accessibility issues in learning platforms

As in any other web platform, LMSs also face the challenge of adapting its content to people with different disabilities. Fortunately, this type of adaptation has been studied by international bodies such as the WWW Consortium, where the Web Content Accessibility Guidelines have been recently upgraded to version 2.0 [40].

In the context of learning, this problem becomes more challenging when creating learning content. An LMS may offer a perfectly accessible environment, but the learning resources that are usually produced outside of the LMS and created by teaching staff (not web designers) may not comply with these guidelines. In Section IX this problem is described in the context of authoring tools.

VII. 3D SOCIAL VIRTUAL ENVIRONMENTS FOR LEARNING

Advances in information and communication technology not only arrive ever more rapidly to our lives, but also produce a tremendous impact on the way we behave. Among the many

consequences of these advances, we have a new generation of learners, so-called Digital Natives [41] with different patterns of work, attention, and learning preferences [42]. Digital Natives usually seek instant gratification, perform several activities concurrently, and behave efficiently in achieving their goals when motivated. Although Digital Natives are not characterized by being empathetic, they easily create new relationships within their own age group and mobilize people for a given purpose [42]. Thus, our main concerns are how to motivate students to learn and how to support teachers to apply instructional strategies adapted to this new generation of learners. In order to achieve our objectives, we explore technologies such as 3D virtual worlds, game design, social computing and e-learning.

A. Contributions from 3D virtual worlds

3D virtual worlds have a set of elements –also present in video games– that may help to seduce students into learning. The use of avatars as representations of students and instructors and the possibilities for customizing avatars, enhance the degree of realism and permit the subject to immerse him/herself in the 3D virtual environment for learning. The 3D scenarios also help to the sense of immersion and open up options of discovering new knowledge by exploring virtual worlds. The ability of avatars to interact with virtual 3D objects in collaborative environments offers new possibilities for the use of learning theories such as experiential learning, discovery learning and constructivism [43][71].

B. Contributions from game design

Games [44] use action instead of explanation and provide interactive content, therefore bring new ways of using teaching strategies [72]. Class activities such as presentation of a lecture can be done by an NPC (non-player character) representing a tutor or several NPCs playing situations that show students a given technique. NPCs can improve immersiveness by acting in plausible ways; their activities can be programmed using artificial intelligence (AI) methods. Deterministic AI techniques such as finite state machines, decision trees or even fuzzy logic are currently being used in video games and non-deterministic techniques such as Bayesian networks, neural networks and genetic algorithms are starting to be exploited in these games [45]. Our 3D virtual learning environments should find which kind of synthetic characters can be used and what AI technique can we apply for programming their behaviors.

Probably the main contribution of game design [44] is the use of rules to achieve specific outcomes to learning experiences, instead of using them with entertainment purposes. Rules are a crucial element in motivation in these virtual and social environments, they can be used to guide students towards acquiring new knowledge as well as for direct the community toward joint learning efforts.

C. Contributions from social computing

The new generation of learners demands social environments where they can explore knowledge by themselves,

connect, communicate, and collaborate with other people in natural ways. Social incentive mechanisms must be used to encourage Digital Native's participation in collaborative tasks. Web 2.0 has opened new ways of communication and collaboration through techniques such as wikis, forums, collaborative tagging, and tag clouds that now must be adapted to 3D interfaces. Social visualization can relate academic performance to status in peer-group and also stimulate social comparison and competition.

D. Integration with learning management systems

A 3D social virtual environment is able not only to integrate a wide spectrum of instructional strategies that engage students in critical thinking learning activities, but also to motivate students, promote wide participation and make subjects easier to learn. Nevertheless, its impact as a pedagogical tool can be enhanced by embedding it in a Learning Management System (LMS) that manages the units of learning created in these learning environments.

E. Technological feasibility and work done

Open Simulator [46], Croquet [47], and Wonderland [48] are open source platforms that are suitable for creating collaborative 3D virtual worlds. They provide features such as avatars, NPCs, text and audio communication, sharing virtual objects and desktop applications and the possibility of transporting avatars between virtual worlds. From a previous study [49], we have decided to choose Wonderland as development platform, because it offers more possibilities for extensibility and has developed its immersive audio capabilities in a more advanced way.

A first collaborative experience was deployed. It consisted of a 3D virtual world, where avatars from several teams explored the world searching for the information a tutor asked them to find. The information was provided for NPCs that performed different dialogues for each learner team. The students were supposed to interact with members of other teams looking for missing information. Finally, the assessment consisted of a test to determine whether the students acquired the academic knowledge and social competences required.

VIII. M-LEARNING

With the steady improvement in the computational capabilities of mobile personal devices and the increasing needs for specialized and personalized training, new m-learning architectures and environments are being defined and used in different ways [50]-[54]. M-learning (and pervasive learning in general) scenarios enhance traditional e-learning scenarios by adding some new important dimensions to the e-learning process such as the anytime, anywhere space-temporal dimension. These new dimensions extend the e-learning concept to a new way of improving the learning experiences by the introduction of personal, context-aware, pervasive services. M-learning provides an "always on" user-context enhanced learning process. As Siobhan Thomas [52] states, m-learning leverages four components in the learning environment:

community driven learning, learning autonomy from the student point of view, location independency and context driven learning. It is therefore not surprising that some projects such as [55] are using mobile devices for e-learning. As Timothy R. Hill states in [56] “emerging mobile technologies hold great promise for educational institutions seeking to extend the learning experience to an increasingly nomadic and time-challenged student community, especially at urban campuses where both faculty and students typically commute to school and struggle to multi-processes work, study and family time and location demands.”

Although there have been significant achievements both in m-learning theory and practice during the last decade, there are yet many open issues that need to be addressed. Some of them can be categorized as technology related, some as pedagogy related, while others can be associated to the motivational impact that the use of mobile devices and pervasive environments have on the student. Technological challenges in m-learning comprise the improvement in the computational capabilities of mobile devices, the increase in mobile network capacity, the improvement in programming languages for mobile devices, the use of embedded sensors, the integration of multimedia content and the ability to interact with smart environments. Pedagogical challenges encompass the use of mobile devices to support face to face activities, the use of mobile technology to reinforce traditional e-learning processes, the use of mobile devices as an always on channel to provide immediate and personalized feedback, the possibilities to control the learning process by learning using mobile devices, the use of a mobile device to support meta-cognitive activities or in social learning environments, or how to use the physical learning context in the learning process in either formal or informal learning environments. Motivational challenges include how to use technology to enhance the motivation of the students, how the increase in the control of the learning process motivates them and how the interaction with smart objects using mobile devices can also be a motivational factor for the student.

Among the different challenges previously mentioned, the UC3M group is currently focused on analyzing, synthesizing and proposing solutions for the use of mobile technologies as a “motivation factor”, as a support framework of new learning scenarios in contextualized learning and for creating adaptive units of learning with flexible learning paths and as a support for meta-cognitive activities such as time management and process awareness. The group develops technological components and deploys them in real scenarios inside UC3M. The components use different types of networks to interact with the learning environment such as NFC and Bluetooth. The real experiments with students measure learning gains as well as motivational impacts.

The UC3M group is currently participating and actively leading some of the activities in two technology enhanced learning research projects: Learn3 and SOLITE. The Learn3 project is exploring and exploiting the synergies in the research work done by the UC3M e-learning group and the GTI group of the Pompeu Fabra University. Some joint m-learning experiments are being carried out with students in both universities gathering data of individual and collaborative

interaction patterns with physical learning objects embedded in the student environment. The SOLITE project aims to align the research of some of the major e-learning research groups in Spain, Portugal and Latin-America. The UC3M group is defining and implementing m-learning activities both in Spain and Colombia, analyzing some of the motivational and learning impacts that the use of mobile devices may have on students in contextualized learning environments.

IX. AUTHORING AND APPLICATION OF WEB 2.0 AND WEB 3.0 TECHNIQUES TO E-LEARNING

At the early stages of e-learning, producing content was the same as publishing a web page or a document for download in the net. With the advances on web content, learning resources are now much more complex, and therefore, much more complicated to produce. The authoring paradigm has shifted from a one-person simple resource production scenario to a variety of production scenarios. De Freitas [57] divides these emerging scenarios into four categories: learner-authored content, practitioner-authored content, commercial and public-sector commissioned content and hybrid approaches.

The trend in authoring environments could be summarized as an evolution toward highly rich, service based, collaborative approaches. The “rip, mix, and burn” paradigm popularized by Apple has an ever increasing presence in the e-learning content production landscape also due to the large number of available resources with flexible licenses such as Creative Commons (see [58] or [59] for an example of such repositories). From this trend, several research venues and results are being considered, and most of them are derived from the ideas previously described in the context of deploying e-learning experiences.

The integration of external services is perhaps one of the most challenging ones. Re-using a resource such an image, a video, an animation, or a document are fairly simple due to the editing capabilities of most learning content production platforms. The challenge now is to raise the re-use of services to the same level of simplicity. Let us illustrate this problem with an example. Let’s assume that an instructional designer is creating a course and as part of its pedagogical strategy decides to use a “blog” as a reflection tool (see [60] for a discussion on how useful a blog could be in a learning experience).

How is such “resource” included in a learning activity? The first approach would be to simply explain to students how to create a blog by themselves in the ever-increasing number of platforms available in the net. But this solution has a poor performance. Students should then relay to the teaching staff the location of such blog, and they would have a wide variety of structures, policies, etc.

The important observation is that a blog is a resource that has what we call an “instantiation” phase. In other words, as opposed to an image, a document, an animation that can be used by an arbitrarily large number of users with no impact, a blog needs to be instantiated as many times as required by the number of users. Learning Management Systems tried at first to provide these services internally, but they were quickly outpaced by highly specialized platforms available in the net.

What kinds of steps are required during the authoring phase to be able to use such a service during the enactment of a learning experience? Current research ideas propose to include a generic description of the service. Such description would include very generic properties such as “blogging tool”, and a set of minimum requirements. For example: authenticated, restricted access to posts, etc. This would partially solve the problem of “including” such resource at the authoring phase.

But the real challenge is to manage the “instantiation” phase, which is no longer required when the instructional designer is creating the resource, but when the experience is being deployed. In this new scenario, this resource or service needs to be instantiated as many times as the experience is enacted, and if the service is in a per-user basis, as many times as users. In [7], this research avenue is explored and demonstrated with a service to provide questionnaires using Google Spreadsheets. The objective of the presented approach is twofold. On one hand, offer the integration of highly popular services emerging in Internet at the authoring phase to truly exploit their potential. On the other hand, achieve a tight integration between the learning experience and the service execution. By “tight integration” we mean that the learning experience should be able to gain insight on what happened inside the service to potentially react to it. This paradigm would truly capitalize in the use of these resources.

There are multiple possible scenarios that can take advantage of this paradigm. The closest one to current state-of-the-art tools is the use of forms for tests or quizzes. The service can be instantiated and the obtained results used to change the structure of an experience. Forums are increasingly present in e-learning, several research initiatives have been monitoring the activities in these forums to then deduce certain conclusions (see [61] for an example). If the service is integrated as described in this paradigm, these conclusions can be used to modify the structure of the remaining activities.

A second research venue being explored is the creation of reusable e-learning content in a distributed authoring environment. The approach combines the use of markup languages (such as docBook) and distributed source code management tools (such as git). The idea is to combine a learning object creation approach with a set of rules that take those objects and create a set of learning resources. The paradigm is being used in a few courses with a high number of content creators and the initial results are promising with respect to the distributed nature of the paradigm and need further improvement to lower the learning curve to use markup languages by the lack of visual tools.

Many developments have been carried out in relation with the Semantic Web since the paper by Tim Berners-Lee, Jim Hendler and Ora Lassila [62] was published in Scientific American, and many keywords have come up since then: Semantic Web, Web 3.0 [63], Data Web, Linked Data, ... Many of these developments have found application for learning. The integration of learning technologies into the Semantic Web enables interoperability not only among e-learning applications and resources, but also with other Web entities, making more powerful interactions and services possible. Service-oriented architectures have been proposed,

which make available Semantic Web methods for e-learning applications, such as for adaptive hypermedia [64].

The creation of ontologies and annotations for e-learning are necessary steps to build Semantic Web applications in e-learning. In this context, ontologies represent a formal knowledge modeling of different learning aspects. The generation of such ontologies implies an extra engineering effort, but they overcome the limitations of traditional e-learning systems [65]. A classification of the different types of ontologies for education can be found in [66]. While there are several works that explain ontologies that are not based on existing e-learning specifications covering different learning issues, on the other hand there are other works that try to adapt and convert existing e-learning specifications into the Semantic Web. In this line, there are RDF Bindings for IEEE-LOM, Dublin Core, IMS QTI, IMS LD, or IMS LIP.

Several applications have been built during the last years that enable to take advantage of the Semantic Web in e-learning. This includes searching applications like Courseware-Watchdog to perform searches based on meta-data [67], or adaptive applications like [68], which personalize learning contents based on reasoning over Semantic Web resources annotated according to defined educational ontologies, or tools like SMARTIES [69] for creating instructional designs based on pedagogical models and ontologies.

Although there is a wide community supporting research on Semantic Web applications in education and ontologies, there are several and important challenges at present. Firstly, even though there are promising works for the generation of automatic annotations and ontologies from text, the provision of easy to use or/and automatic tools that generate annotations and ontologies in Semantic Web formats for all the different aspects of e-learning is a challenge. These tools should provide ideally automatic and complete modelling for the knowledge domain through the ontologies, as well as correct annotations, being aware of the changes during the time.

The distributed vision of the Semantic Web also leads to the problem of compatibility among different ontologies and annotations among different systems. Some promising ideas have been proposed, but more effort should be made regarding this issue to be able to connect the different e-learning systems.

Another important open issue is the integration of a lot of existing traditional e-learning systems into the Semantic Web, so that the advantages of the Semantic Web can be taken. This implies an effort for defining ontologies, making annotations, adaptive rules, etc. according to the specific particularities for the different applications.

The UC3M group has contributed to the integration of existing traditional e-learning systems and services in the Semantic Web. In this direction, a new architecture for combining Semantic Web techniques with Intelligent Tutoring Systems has been defined, which combines traditional e-learning formats with Semantic Web ones, and a prototype for achieving adaptive hints according to the defined architecture has been implemented [70]. This development separates the adaptive rules for execution in a Semantic Web reasoner, while

keeps the non-adaptive functionality for generation of hints in a traditional e-learning tutor.

CONCLUSION

In this paper, we have presented the many research lines carried out by the UC3M group of eMadrid in the context of e-learning. The field of learning has always profited from the advances in ICT. Presently, we have a wealth of new developments that are directly applicable. At UC3M, we follow several of them that in a synergistic way enriching one another.

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