Towards an Effective Evaluation Framework for IMS LD-Based Didactic Materials: Criteria and Measures

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Abstract. Evaluation is one of the most important activities in the didactic materials development process since it allows developers to check if the obtained material satisfies all requirements and it also provides developers with reliable information about material's utility, validating if the obtained material can be effective support in the achievement of the educational goals which it intends to support. Evaluation results provide valuable information for the material redesign in such cases when the requirements or educational goals are not satisfied. Nevertheless its importance, the evaluation has been often neglected in most of the approaches related to the development of didactic materials, which are more focused on issues such as interoperability or reusability. In this paper we present the MD2 evaluation framework based on a general evaluation procedure that include a set of criteria and measures for the two more important evaluation objectives of IMS LD-based didactic material: its usability and pedagogical usefulness.

Keywords: Didactic materials, Learning Objects, Units of learning, Development Methods, Evaluation, Pedagogical Usefulness, Pedagogical Utility, Usability.

1 Introduction

New educational models and the widespread use of didactic materials compliant to e-Learning standards have promised to face challenges of the modern education. But those efforts will be worthless without the means to control that users involved in the deployment of educational process can effectively reach their educational goals.

Didactic materials are any kind of digital (or not digital) elements that assist actors of the teaching/learning process to achieve their objectives 8. They are herein considered as the conjunction of contents and a pedagogical strategy, which is defined by an instructional design and is used to guide learning and teaching processes. The didactic material creation process consists in a set of phases: analysis of requirements, design, development or implementation and evaluation 15. This creation is a complex process which needs to rely on frameworks defined by development methods in order to ensure effective, systematic and rational solutions. Also high-quality authoring environments based on such methods are needed to effectively help and guide developers dealing with the complexity of the process. Thus, the MD2 approach aims

J. Jacko (Ed.): Human-Computer Interaction, Part IV, HCII 2007, LNCS 4553, pp. 312–321, 2007.

to achieve those endeavours by means of the MD2 development framework. Such framework is based on the MD2 model, which describe main didactic materials knowledge-domain, pedagogical and technical requirements and the MD2 method that guides the didactic material development process 18. The evaluation is one of the most important activities in the didactic materials development process since it allows developers to check whether the obtained material satisfies all requirements and it also provides developers with reliable information about material's utility, validating if the obtained material can be effective support in the achievement of the educational goals which it intends to support. Evaluation results provide valuable information for the material redesign in such cases when the requirements or educational goals are not satisfied. In spite of the recognized value of evaluation, it has been neglected in most of the current approaches to the didactic materials development like RELOAD 19 or CopperAuthor 2. Those approaches have in common the successful technical implementation of learning technology standards and specifications such as IMS LD 9, IMS LOM 11 and ADL SCORM 21. Their use represents a further step in order to ensure the interoperability, accessibility, reusability and personalization of the obtained materials but those efforts will be worthless if there are not means to control the effectiveness of such obtained materials. We understand that evaluation is a crucial phase in the didactic materials creation that's why in this paper we analyze how the procedures and metrics proposed to assess educational hypermedia applications 3451623 can be applied to the evaluation of IMS LD-based didactic materials. In section 2 we present a general evaluation procedure and we elucidate how it can be applied to evaluation of IMS LD-based didactic materials. Next, we explain the selection of material evaluation objectives and explore the applicability of some metrics and measures proposed by previous evaluation studies for educational hypermedia systems. In section 3 we explain how evaluation has been integrated in the framework provided by the MD2 approach. And finally in section 4 some conclusions and future works are outlined.

2 Didactic Materials Evaluation

Educational hypermedia system has been defined as an ideal framework for the deployment and coordination of supporting techniques and tools for educational processes 7. It allows modelling and representing didactic materials in such a way that educational process can be provided with appropriated principles and strategies for it harmonic development 14. In this paper the following definition of didactic materials is used: "A didactic material is the conjunction of a set of contents, in form of learning objects, with a pedagogical strategy defined by an instructional design, which takes the form of units of learning and guides the educational process". This definition considers from a technical view based on the IMS LD specification (de facto-standard) that such material is an specific type of educational hypermedia system since learning objects and units of learning have hypermedia structures composed by nodes and, content and structural links. The nodes include information related to educational goals such as knowledge acquisition, skills and attitudes. Moreover the didactic material structure based on the relations between contents and the pedagogical strategy is represented by structural links. Díaz in 3 has proposed an

extension to general evaluation procedure aiming to guide the usability evaluation of educational e-Books. The following steps made up that evaluation procedure: Definition of the evaluation objectives; Selection of evaluation technique; Set up the evaluation; Evaluation development; Analysis of evaluation results.

The aforementioned procedure can be adapted to assess didactic materials. In relation to the definition of evaluation objectives, there is a set of material desired features needed to check such as: its reusability, compliance to the e-Learning standards and specifications and acceptable quality. Since the above didactic materials definition already ensures the compliance to e-Learning standards, the other features must be considered in the selection of evaluation objectives. Material quality can be analyzed from the product point of view and HCI perspective as its usability and from the pedagogical view as its educational usefulness or pedagogical value. Meanwhile its reusability is based on its capability to be used in different learning situations or in diverse knowledge domains 18. Hence, the didactic materials evaluation must be carried out in two stages: first stage as formative evaluation during materials development, where the evaluation objectives would be quality and usability. And the second stage as a summative evaluation to assess materials quality, usability and to check the reusable nature of materials, once the educational process has concluded. In this paper we will focus on the formative evaluation and we analyze the means to ensure an appropriated summative evaluation. In the next sections we explain how to apply the rest of evaluation procedure steps to the formative evaluation of didactic materials.

2.1 Evaluation Objectives for the Evaluation of Didactic Materials

Once the evaluation objectives are chosen (material usability and pedagogical usefulness) we need to define which evaluation metrics and parameters should be used to assess those objectives.

2.1.1 Pedagogical Usefulness Criteria

Diaz et al. had defined in 4 a set of metrics and criteria for each one of the didactic materials evaluation objectives. Most of those criteria require subjective assessments that are inherently vague or are derived from estimations that entail some imprecision or uncertainty. That is why a subset of Smet's taxonomy of imperfect information 22 has been used to characterize the different potential manifestations of uncertainty and imprecision founded in those measures. Imprecision and inconsistency are essential properties of the information itself whereas uncertainty is a property of the relation between the information and our knowledge about the world. Imprecision and inconsistency are properties related to the content of the statement: either more than one world or no world is compatible with the available information. Uncertainty is a property resulting from a lack of information about the world, in order to decide if the statement is true or false 22. The suggested criteria to evaluate pedagogical utility are: Richness, Completeness, Motivation, Hypertext structure, Autonomy, Competence or Effectiveness and Flexibility. Next we analyze how they can be used in the evaluation of IMS LD-based didactic materials.

Richness: It is a criterion used to express and assess the amount of information included in the material, the different ways to explore that information and the

availability of diverse presentation formats. For the latter is very important to check if material can satisfy users' needs (learners) with different skills, capabilities and learning styles. With respect to the different types of access to information, it is worth noting that units of learning, described by IMS LD (level B) 9, have already considered diverse kind of users (academic staff and learners) and offer mechanisms for the material presentation adaptation to users characteristics, if those features have been modelled as properties and they can be managed based on certain conditions. Hence, the most important aspects to consider for evaluation of this criterion are the amount of presented contents, the number of educational objectives addressed, and the different presentation forms and adaptations to users' characteristics. Those aspects will be shown to evaluators in form of linguistic expressions or linguistic measures scales since humans are more familiar and comfortable with them for evaluation purposes. Such kind of expressions has imprecise nature 22 and the most appropriated evaluation techniques are expert or heuristic analysis.

Completeness: This criterion allows us to asses if material is provided with enough contents to reach the established educational goals and whether its implemented interaction mechanisms are suitable to support users in the achievement of their educational goals. Completeness is different to the previous criterion, since richness is just concerned with the amount of information. The inclusion of any communication support for the educational process stakeholders is one of the aspects to take into consideration when completeness is assessed. It has been also considered in IMS LD and different mechanisms are defined to allow communication amongst participants: i.e. asynchronous communications like email and fora, and synchronous such as chats and videoconferences. Consequently during the evaluation of this criterion must be controlled if the implemented communication mechanisms are appropriated and really foster the achievement of stated educational objectives; and whether the amount of presented contents is enough and suitable to achieve those goals. Those aspects will be presented to evaluators in form of linguistic expressions or linguistic measures scales. The most adequate evaluation techniques for such kind of imprecise information are expert or heuristic analysis.

Motivation: It let us evaluate if mechanisms implemented in the material ease its use and encourage the achievement of participants' educational goals during the learning process. The author in 4 has proposed to analyze if any self-evaluation mechanisms are provided and whether they give some feedback to students in order to correct their misunderstanding and errors. She also recommended checking out if some personalization is provided to adapt material to particular learning styles and promote students motivation. All those aspects, rather than evaluation elements, should be considered as design and development guides to ensure students motivation aiming to reach their learning objectives. Thus, this evaluation criterion must analyze if self-evaluation activities included in the structure of units of learning help students to get deeper understanding of contents and whether those activities' feedback contributes to improve or maintain learner's motivation. Those aspects will be presented to evaluators in form of linguistic expressions or linguistic measures scales, but in contrast to the previous criteria they have a subjective and uncertain nature, hence the most appropriate evaluation technique is the experimental evaluation during the learning process development in order to examine tangible evidences of participants' motivation.

Hypertext structure: The goal of this criterion is provide developers with objective measures to detect problems in the material structure 1 23. Some of the parameters suggested by Díaz in 3 for this criterion are connectivity, modularity, balance, use of hierarchical structures to ease navigation and to avoid space disorientation. For the type of didactic materials we are concerned, the previous parameters except balance have been already considered in their IMS LD definition. Such definition ensures the modularity of activities structures and their resources, and also establishes a proper hierarchical organization and connectivity; consequently each element of those structures is always accessible. In relation to the balance, defined by Botagofo in 1 taking into consideration that hierarchical structure of hypermedia documents can be represented with tree data structure. A hypermedia document is balanced if each node of its structure has a uniform number of child nodes. Moreover the definition of balance for educative hypermedia systems presented in 3 like "a system is balanced if all included subjects or topics are presented with a uniform amount of information" stressed on the relation between the balance and the amount of details presented for each topic included in the material. Thus, when the structure of IMS LD-based didactic material is assessed should be controlled if all topics have been presented with similar amount of details. Such evaluation can be implemented through automatic measuring techniques to control the balance of the material hierarchical structure.

Autonomy: It is defined as freedom provided to the user for her interactions. This aspect must be controlled to avoid hyperspace disorientation, accordingly to evaluate a material it must be checked if material structure eases the navigation and helps user's orientation considering her interaction profile (i.e. personal characteristics and preferences) 4. The IMS LD Best Practice and Implementation Guide 10 recommends that LD players should use representation mechanisms for the unit of learning structure that provide target audience with guides for navigation and clues to avoid disorientation during their interactions. Although all current LD players are implemented following such recommendations, this criterion should be always considered for the evaluation of didactic material's pedagogical value. The assessment of this criterion must be presented in form of linguistic expressions or linguistic measures scales. The most recommended evaluation technique, that takes into account the subjective and uncertain nature of this criterion, is the experimental evaluation during the deployment of learning process. That evaluation will check out whether the level of autonomy provided to the target audience has a proper correspondence with each user profile.

Competence or effectiveness: This criterion is related to the ability to navigate through the system and to reach a particular goal 3. When this criterion is assessed, the material's adaptation capability to different users' expertise level must be controlled. For materials designed as units of learning, this criterion can be used to assess if material can be adapted to different interaction styles and whether their contents are appropriated for different types of users. Although such adaptations can be achieved thanks to level B of IMS LD, when we are concerned with the competence evaluations it will be needed to check out if the implemented adaptation mechanisms, based on properties and conditions, effectively help users in the achievement of their educational goals. Those evaluations should be carried out during the deployment of the educational process in order to control the material effectiveness.

Flexibility: If a system can be easily used, accessed and maintained it is a flexible system 3. The material accessibility should be two-fold analyzed: from technical and human views. The first one is related to hardware and software restrictions meanwhile the second one takes into account physical and time restrictions. The didactic materials, we are analysing, are web systems characterized by their flexibility since they are platform independent without time and space limitations for their use. Nevertheless, their design can establish certain restrictions for specific instructional situations. Regarding to their maintenance, IMS LD and QTI 12 advocate for a modular and well-formed structures that facilitate not just the material maintenance but also improve the reusability nature. Thus, elements from the units of learning such as acts, activities, structure-activities and environments (i.e. services and learning objects) or items of QTI tests can be reused in similar instructional situations or when new materials are created. This criterion should no be considered in the formative evaluation of materials when IMS LD or IMS QTI has been selected as foundation of material structures since them already ensure flexibility. But it should be used in the summative evaluation to check out if there are influences of such flexibility on the material reusability.

2.1.2 Usability Criteria

The second evaluation objective for didactic material assessment is usability and Díaz in 3 defined some criteria like Aesthetics, Consistency, Self-evidence and Predictability to assess this objective. Nevertheless the usability has been considered out of the scope of the IMS LD specification, it is an important aspect to take into account when the effectiveness of IMS LD-based didactic materials is analyzed. That is way in this subsection we briefly explain how each of previously mentioned criteria can be applied to the didactic materials evaluation.

Aesthetics: It defines whether the design of material's user-interface enhances the comprehension of its contents and their legibility. This criterion allows us to analyse if contents are harmonically and well synchronized presented in order to ease their comprehension. One of the aspects to be considered when this criterion is evaluated is content density i.e. the amount and complexity of contents presented in the material. Other aspects are the legibility of each element presented in the material, the material's general legibility, and also the suitability of contents to fulfil requirements of the learning process and the characteristics of its stakeholders. Measuring instruments or mechanisms for this criterion, that has inconsistent nature and multiple facets, should use the aggregation of measuring results from its different aspects in order to obtain the final assessment value for aesthetic. For instance, appropriateness and density are imprecise data 22 that should be assessed by developers; meanwhile legibility can be automatically measured using Fog index 13.

Consistency: Consistency refers to the extent in which conceptually similar elements are treated equally by the application, while those that are dissimilar are treated differently 5. If the material is consistent, then it is easier to use and remember and an important cognitive load is released. Thus, users can focus in the development of tasks that allow them to reach their educational goals. This criterion has been already considered in the design of IMS LD (and QTI) player according to IMS LD (QTI) Best Practice and Implementation Guide, thus will be no necessary to consider it for

the didactic material evaluation. But it should be used in the summative evaluation to check out if the obtained material is really consistent.

Self-evidence: This criterion allows determining how easy material users can guess the meaning and purpose of each of the elements presented in its interface 5. Hence we can analyze how tangible are the material structure and its functionalities. Self-evidence will also allow checking if content presentations are clear and unmistakable. Self-evidence should be assessed considering the subjective and uncertain properties of linguistic measuring scales or expressions 22. The most recommended evaluation technique is the experimental evaluation during the educational process deployment, since it is the most suitable to control if material contents has been presented clearly and accordingly to the learners knowledge levels.

Predictability: To which extends users can anticipate results of their specific interaction with the material can be defined as predictability 5. It is different to self-evidence since the latter allows identifying purpose and functionality of presented elements but it does not allow predicting their results. The predictability can be used as recommendation for material interface design to ensure an easy interaction. In the case of IMS LD-based materials, although it has been considered in the design of LD and QTI presentation and delivery engines, it should considered in the summative evaluation to obtain reliable information about material predictability.

There are other general criteria to assess usability like error frequency and severity, familiarization time or efficiency of use 17 that should be also considered in the evaluation of material usability, since they have an important influence in the effectiveness of material to support users in the achievement of their specific goals.

Errors frequency and severity: This criterion is useful to check the influence of material design in the frequency of errors made by users during their interactions with the material. It is also concerned with assessing the severity level of such errors. It is unacceptable that material interface will induce users to make important mistakes that hinder the successful development of their tasks. Hence this is an important fact to notify to material developers in order to be fixed during the material interface re-design. Linguistic expressions and measure scales will be presented to evaluate this criterion. Since they have an imprecise nature 22 the heuristics and expert analyses are the most recommended techniques to evaluate errors frequency and severity.

Familiarization time: It is used to determine how easy to learn is the didactic material. This element helps to identify how fast users can interact with the material interface in order to reach their goals during their first use of the material. For this criterion will be used a reference value in hours:minutes:seconds format. It will be restricted and should not exceed a third part of the defined estimated effort to achieve the stated competences, skills or learning objectives. This criterion could be assessed by usability and design experts during the formative evaluation. But the most recommended evaluation technique for this criterion is experimental during the deployment of educational process. Therefore we can gather real evidences of how fast students become familiar with material's interface during their first interaction.

Efficiency of use: It allows us to decide to which extend the use of material ease the proper development of users' tasks. This element should be used in the assessment of

material once the user is familiar with its interface. Thus, the previous criterion can no be considered as influence for the efficiency of use measure, however error frequency and severity does have important relation to this criterion. It will be unacceptable that design of material interface will no help users in the development of their task. Thus, this fact must be informed to material developers in order to proceed with the material re-design. The most adequate technique for the evaluation of this criterion is the experimental evaluation to control if material can effectively support participant to reach their goals during the deployment of the learning process.

3 The MD2 Method and Its Evaluation Framework

Once parameters and metrics to assess the evaluation objectives are selected and their evaluation techniques have been chosen, the results of every element criteria must be computed to obtain evaluation objectives global assessment according to the general evaluation procedure. If the diversity of elements nature for each criterion is considered, then aggregation mechanisms should be used to obtain the global values for each evaluation objective. The imprecise, uncertain or inconsistent character of many of the aspects to consider for the evaluation criteria is the rationale behind the use of mathematic theory tools for their representation and to get a measure of the precision for the material evaluation. Among them, fuzziness can be used as information and knowledge representation for some of the measurement instruments for Completeness, Richness or Coherence. Especially the sets of linguistic fuzzy labels and aggregation operators like Linguistic Weighted Averaging (LWA) and Linguistic Ordered Weighted Averaging (LOWA) 6 has been proven as useful to manage with imprecise measurement scales. As we had previously explained some aspects of the evaluation criteria such as Richness and Balance can be automatically measured.Other aspects need to be judged by materials developers, like Completeness, Richness, Accuracy, Self-evidence, Frequency of errors, etc. Meanwhile Efficiency of use, Familiarization time, Effectiveness and Autonomy should be assessed during the educational process development or deployment. Thus, for the formative evaluation the first two options will be combined.

In the MD2 approach 18 the model generally describes didactic material's features like its contents, pedagogical, technical and quality requirements. A subset of MD2 model elements, UQ view elements, are used in the evaluation phase to guide the checking related to the fulfilment of requirements and, to control the usability, pedagogical value and quality of created material. Those elements are based on a subset of the presented aspects for usability and pedagogical usefulness criteria and they are used during the evaluation phase to provide developers with certain confidence information about the quality and pedagogical value of the created material.

The implementation of the MD2 method for evaluation stage in the MD2tool (see Figure 1) presents to developers a web-based evaluation questionnaire. Developers are asked to assess the selected evaluation criteria for pedagogical usefulness (or pedagogical value) and usability. Each of those aspects has to take a value belonging to a delimited interval which is represented in the form of fuzzy linguistic scales. Then those criteria are properly grouped in such a way that implemented fuzzy aggregation mechanisms are used to compute the global values of usability and

quality measures. And their results will be compared to the minimum acceptable values that are defined according to the specific usability and quality thresholds. If the result of such comparisons is not positive, then the influence of each criterion is analyzed in order to provide effective recommendations for material redesign.

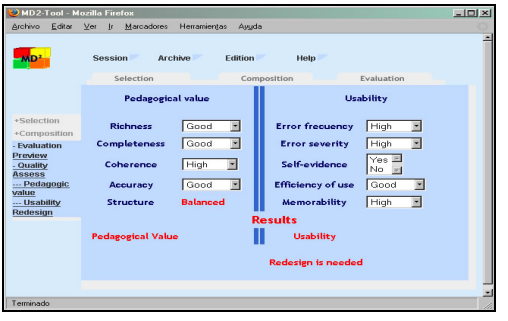

Fig. 1. MD2tool and the didactic material evaluation

4 Conclusions and Future Works

In this paper we have presented an analysis of how to apply the metrics and measures suggested for Hypermedia Educational systems evaluation to the formative evaluation of didactic materials with structure and behavior defined with IMS LD. We had stressed the importance of formative evaluation as mean to provide developers with some reliable information about the quality of didactic materials based on their usability and pedagogical usefulness assessments. We also present how the MD2 model U-Q view descriptors are used to check if features of obtained material satisfy usability and quality requirements. The implementation of evaluation mechanisms in the MD2tool has been briefly presented.

Acknowledgements. This work is part of the MODUWEB project (TIN2006-09678), funded by the Ministry of Science and Technology, Spain.

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