Towards an Instructional Design Methodology Based on Learning Objects

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Abstract: Instructional System Development (ISD) is a set of procedures for systematically designing and developing instruction. The development of contents for e-Learning can well benefit from the ISD approach. However, we need to revisit the traditional ISD in order to incorporate the Learning Object (LO) paradigm. LOs are self-contained chunks of online content, which can be reusable and interoperable. In this work, we propose a methodology to design e-learning contents based on the ISD and LO technologies. We also suggest the use of learning theories principles in the chunking and sequencing of LOs in e-Learning modules. The methodology is currently being tested by K-12 teachers from public schools as well as instructional designers from private companies in Brazil.

Keywords: WBE, Instructional Design; Learning Object; Instructional System Design, ADDIE.

Resumo: Instructional System Development (ISD) é um conjunto de procedimentos para estruturar e desenvolver sistematicamente o ensino. O desenvolvimento de conteúdos para e-learning pode se beneficiar da abordagem ISD. Entretanto, é preciso revisitar a abordagem ISD tradicional de forma a poder se incorporar o paradigma de Learning Object (LO). LOs são porções de conteúdo online autocontidas, que são reusáveis e interoperáveis. Neste trabalho nós propomos uma metodologia para projetar conteúdos de e-learning com base nas tecnologias de ISD e LO. Nós também sugerimos o uso de princípois de teorias de aprendizado no particionamento e sequenciamento de LOs e módulos e-learning. A metodologia está atualimente sendo testada por professores de ensino médio e fundamental de escolas públicas bem como projetistas instrucionais de empresas privadas brasileiras.

Palavras-chave: Educação baseada na web, objeto de aprendizado, Projeto de Sistemas Instrucionais, ADDIE.

1. INTRODUCTION

There is no doubt that e-Learning is critical to the success of individuals, organizations, communities and economies in the knowledge age. The globalization of the economy, shortage of skilled workers and teachers, free agent mentality, new flexible work situations and numerous other factors have created problems not easily solved by the traditional education [1]. The academic, corporate and consumer markets will all benefit from the advantages that interactive, just-in-time, current and user-centric education tools offer. The power of the e-Learning is to deliver the right information and skills, to the right people at the right time and, preferably, at the right cost. However, technology is just one aspect of e-Learning. In order to be effective, there is a need for sound pedagogical methods and techniques to be applied in the design and development of on-line contents.

Instructional Systems Development (ISD) is a set of procedures for systematically designing and developing instructional materials [2]. Although it has traditionally been used in the development of course for the traditional setting, it becomes more important in distance education. Learning Object (LO) which is at the core of a whole new courseware design paradigm requires a radical change in instructional design strategies, technical architectures and delivery systems. How does ISD deal with this new technology?

There are numerous definitions of a learning object, but it is basically a small "chunk" of learning content that focuses on a specific learning objective [1]. The learning objects can contain one or many components, including text, video, images or the like. LOs may be seen as building blocks that can be combined in nearly infinite ways to construct collections that might be called lessons, modules or courses [3]. The idea is to increase learning effectiveness while reducing time and costs.

Too much work has been devoted to establish technical standards for the e-Learning industry aiming at the interoperability, reusability, accessibility and affordability of LOs [4]. However, more attention should be given to establish instructional theories or methods so that one can take the greatest advantage from the application of the LO paradigm. The choice of which learning objects to assemble into a collection can be a decision made in advance by an instructional designer or at the moment by a student. In line with [5], and in light of the technological advancements, we should not consider the ISD as obsolete, but rather revisit it with new strategies, methods and techniques.

This work aims at proposing an ISD/LO-based methodology for the design and development of educational content to be delivered via the Web. An analysis was carried out to determine the impact of the LO approach on the traditional ADDIE model [6] and how it should accommodate the development of contents on a reusable and modular fashion. This methodology is being developed in light of the requirements of the PGL Project [7]. PGL is an international initiative to design and produce e-Learning contents for the corporate, academic and consumer market on a global scale. As part of the PGL project, a multimedia e-learning oriented distributed database system is being developed to serve as a LO repository in the PGL environment.

The remainder of this paper is organized as follows. In Section 2, related work with emphasis on the CISCO´s Reusable Learning Object Strategy, which is also related to the ADDIE model, is presented. In Section 3, the adjustments to the traditional ISD model arising from the application of the LO approach are shown. In Section 4, we present the methodology with its outputs and phases. In Section 5, the results of the application of the methodology by k-12 teachers and instructional designers during a course run by PUC-Rio are reported. Finally, in Section 6, some concluding remarks are made.

2. RELATED WORK

In [8], the CISCO Strategy is proposed where four phases for building Reusable Learning Objects (RLO) or Reusable Information Objects (RIO) are presented. The RLO-RIO structure defined in this work proposes a hierarchy in which a RIO is the leaf component of a more complex RLO structure. However, a RLO should be limited to around 7 components. The development strategy proposed includes typical phases such as Design, Development, Delivery and Evaluation. The CISCO strategy also provides detailed guidelines for the creation of RLOs and RIOs. However, although it presents the hierarchy RLO-RIO to structure LOs, it does not clearly address the issues on how to chunk and sequence LOs. Additionally, no clear statement is made on how the methodology relates to instructional theories.

The ITT theory proposed by Merril [2] describes knowledge in terms of three types of objects (entities, activities and processes). The theory defines a set of instructional algorithms called transactional shells, which are reusable. The program uses the same algorithm repeatedly with different learning objects.

The Learning Object Design and Sequencing Theory - LODAS is being developed by Wiley who considers the issues of LO granularity and sequencing of ultimate importance in designing instruction. He combines four existing instructional theories namely Elaboration Theory, Work Model Synthesis, Domain Theory and the Four-Component Instructional Design Model into LODAS theory. His theory also provides a taxonomy for LOs and design guidance for the different types of LOs [10].

In [11], principles of LO design are presented and accompanied by guidelines to ensure that instructional content is designed and tagged for modularity and reuse. The emerging courseware standards do not yet provide specific guidance for designers on how to create LO. However, recognizing that there are some principles and guidelines available in the literature, this work aimed at

compiling five principles to provide guidance on the size and instructional content of LOs, and on how to give context within an instructional track and still how they should be stored in a repository for future use.

In [12] there is an attempt to verify how instructional design based on LOs relates to training plans and personal strategies to acquire knowledge and skills in continuing education. To this end, the investigation is based on a real telemarketing course using the LO methodology found in David Wiley [13]. It was verified that the atom metaphor used by Wiley was useful in that some objects may be combined and other not. The design of LOs was made in 4 stages: Evaluation and reorganization of content in self-contained units; selection of the most adequate objects/classes for learning objectives, relationship between the scalability and reusability attributes and, finally, design of objects. The investigation concluded that the relationship between LO and knowledge management are not only evident but also necessary. Additionally, designing e-Learning based on LO allows for more flexibility and a constructivist approach in the design of instruction.

From the above we consider ITT and LODAS as instructional design theories that could be used to support a design methodology based on LO. The work in [11] is focused on principles not procedures. It could be useful to be a reference for designing procedures as part of a methodology. Finally, the work in [12] reinforces the use of some principles advocated by Wiley. It also contributes in the direction that the LO paradigm can facilitate the development of instruction on a more constructive basis.

Finally, we recognize the CISCO strategy as the starting point of our work. Our proposal, however, goes further because it emphasizes the application of principles of learning theories and user interface aspects. Moreover, the issue of chunking and sequencing of LOs are also addressed.

3. ISD WITH LOs

Instructional Design refers to the process of instructional program development from start to finish. Many models exist for different levels of instructional design and for different instructional purposes; however, we will start from the general method named ADDIE, which includes the following phases: Analysis, Design, Development, Implementation and Evaluation [14].

3.1 UPDATING THE TRADITIONAL ISD (ADDIE) BY THE LO PARADIGM

Considering the LO paradigm the phases of the traditional ADDIE may now be modified as follows: The Analysis phase should now consider the existence of available LOs and its reuse of the solution delivery. Also the monitoring of access to LOs in a database could reveal possible performance problems. The traditional Design phase is now complemented by the idea of LO mining based on valid metadata. Additionally, one should consider that a single LO could be used to support multiple delivery types and that its longevity goes much beyond one-time event. At this stage, LOs can be used as they are or repurposed to meet the instructional needs. The traditional Development stage is now named Development, Repurpose and Reuse. There will be still some more content mining, if the designer sees the potential for reuse. Tools for authoring and assembling LOs will be needed as well as traditional ones for creating sound, graphics, video etc. LOs and media elements should then be connected to form the hierarchy of the solution. Or, differently, LOs may be copied and repurposed, but it leads to many copies of the same object. Writing Style and Guidelines should be provided to ensure maximum reuse, granularity and delivery options. Finally, this phase also includes the authoring, reviewing and editing of metadata. As for the Implementation phase, it is now named Delivery and Access. One implication of the LO approach is that access to the solution can be made in different ways; additionally, the LO-based delivery system can support on-demand training or performance support. Another important change brought by the LO is the ability to track their use, normally through a Learning Management System (LMS).

Finally, the Evaluation phase will need to consider the right timing to carry out evaluation on the performance, but new sources of data will be available and direct learner feedback will also be possible.

In the following section we present a methodology, which considers the analysis above and also the application of principles from learning theories.

4. A METHODOLOGY TO DEVELOP e-LEARNING MODULES BASED ON LOs

First, let us examine how the three basic learning theories (*Behaviorism, Cognitivism, and Constructivism*) influence the proposed methodology.

The primary focus of the *behavioral* perspective is on behavior and the influence of the external environment in shaping the individual´s behavior. As such, the primary responsibility of the instructional expert is to identify and sequence the contingencies that will help students learn. Teachers should then state the objectives of the instruction as learners' behaviors. Learning is inferred from behavior, so it is important to identify the goal behavior, this involves breaking that goal behavior into a set of simples behaviors and arranging them in a sequence of frames that will help students progress toward the goal.

While the behavioral perspective has an external focus, the *cognitivist* has an internal one. Learning is described as a change in knowledge stored in memory. As a consequence, the instructional expert is challenged with organizing new information for presentation, carefully linking new information to previous knowledge and using a variety of techniques to guide and support student´s mental processes.

The *constructivist* perspective describes learning as a change in the meaning constructed from experiences. Learning is constructed by the complex interplay among students´ existing knowledge, the social context and the problem to be solved. The instructional designer should be able to pose good problems, create group learning activities and guide the process of knowledge construction [16].

The proposed methodology follows principles from the three basic learning schools. Behaviorism and cognitivism both support the practice of analyzing a task and breaking it down into manageable chunks, establishing objectives and measuring performance based on those objectives. While behaviorism is highly prescriptive in nature, constructivism calls for no pre-specified content; the learners and no rigid assessments determine the instructional direction. Bearing in mind that each particular theory will be more useful depending on the context, an eclectic approach is recommendable, such as Reigeluth´s Elaboration Theory that organizes instruction in increasing order of complexity and moves from prerequisite learning to learner control [17]. The learner can be introduced to the main concepts of a course and then move on to more of a self directed study that is meaningful to him and his particular context, in line with a more constructivist view. In Section 4, we comment on how instruction can be sequenced based on the Elaboration Theory.

4.1 THE METHODOLOGY´S PHASES AND OUTPUTS

Phase I. Analysis

This phase is aimed at analyzing what is the learning problem and determining the learner profile. Data gathered during this phase are important to make sure that personalization and customization issues will be taken into consideration.

This phase generates the following outputs:

a) Learner Profile Analysis Form

b) Problem Analysis Form

c) Existing LO (if available)

d) Environmental Analysis Form

e) Metadata

This phase encompasses the following procedures:

I.1 Specify Learner Profile: One should be familiar with the learner characteristics by analysing the motivational, technological, demographic profile of the LO user. Items such as age, grade, educational background, etc. should be considered. The application of learning style models [18] are also useful for this analysis.

I.2 Conduct Problem Analysis: It is necessary to determine why the instruction is needed. For corporations, this is normally associated with a performance gap, which should be corrected. In the academic context, other variables should be taken into consideration. One important output of this step is to determine the major learning objective to be accomplished.

I.3 Search the Web or the DB environment for existing LO: If a LO is found and meets the learning needs, then one should consider to use it. It may need to be repurposed or can be reused as is.

I.4 Conduct an Environmental Analysis: One should consider if an instructor would lead the instruction, if there is a Learning Mgmt System (LMS) available etc. Costs and administrative issues are also important.

I.5 Keep Metadata: All data gathered during this phase should be used to generate the metadata according to standard metadata, e.g. IEEE-LOM.

Phase II. Design

This phase is aimed at designing the instructional content and the "look-and-feel" of the LOs´s interface.

This phase generates the following outputs:

a) Task Analysis Document

b) Content Analysis Document

c) Sequencing of LOs (Conceptual Map)

d) Metadata

e) Storyboards of LOs´s interface design

This phase encompasses the following procedures:

II.1 Conduct a Task Analysis: Based on the major learning objective established during the Analysis phase, one should now decompose it into sub-objectives, in such a way that a tree is generated showing pre-requisites sequences to be followed.

II.2 Conduct a Content Analysis: While the task analysis asks what the learner should be able to do (what behavior he should demonstrate) to accomplish the major learning objective, the content analysis asks recursively what the learner should know to perform the foreseen tasks. This analysis will reveal the concepts, principles or procedures, which should be learned or taught.

II.3 Identify LOs structure: Based on the tree generated by the task/content analysis, one should now chunk the content into a structure of LOs. This chunking should observe the following principle: After defining the hierarchical tree of learning objectives, it is recommended that a minimum of 3 and a maximum of 7 items be presented at each elaboration level for a given aspect of the epitome. The minimum is due to cataloguing expenses and the maximum is due to the capacity of short term memory [19]. Therefore, a LO at elaboration level ***n*** would combine between 3 and 7 LOs from the elaboration level ***n+1***. Some LOs will be smaller while others will be

larger, since they will be composed by LOs from a higher elaboration level.

II.4 Establish the Sequence of the Instruction: This will indicate the sequence in which the LOs will be delivered. There are a number of ways to sequence instruction, but we recommend the one prescribed by the Elaboration Theory. It uses the concept of epitome, progressive differentiation and reconciling integration, by advocating a top-down approach [20]. The epitome should be presented first, followed by the various elaboration levels. For sequencing, the hierarchical tree should be crossed from the left to the right at each elaboration level.

II.5 Categorize LOs: After identifying the LOs, one should now assign a category type to them. We use the one proposed in [9] and [8]. At the bottom level, each LO has to do with a cognitive level, such as Principle, Process, Procedure, Concept and Fact.

II.6 Specify the LOs: For each LO the following attributes should be specified: learning outcomes, content to be covered, evaluation method, example, practice, media and instructional approach. This last item can be chosen among the following cases: presentation, demonstration, collaborative learning, learning by discovery, problem solving, instructional games, simulation, tutorial and drill-and-practice.

II.7 Keep metadata on content design: All data generated during this phase should be used to create the metadata according to standards, such as the IEEE-LOM

II.8 Model the user for the LOs' interface design: The data gathered during the analysis phase should be useful to help determine the profile of the user interface.

II.9 Carry out user task analysis: This focus on the tasks the user will perform with the LOs.

II.10 Find a metaphor: A metaphor will make the interface more intuitive. One should however pay attention to cultural issues.

II.11 Design the interface "look": Colors, fonts, icons and all visual aspects should follow sound interface design principles. Internationalization and localization issues should be considered.

II.12 Design the interface "feel": The site topology, navigation and interaction tasks and other interface components should be chosen following sound interface design principles. Internationalization and globalization should be considered.

II.13 Prototype and evaluate: Storyboards with interactive, visual and audio aspects should be developed to specify the "look-and-feel" of the LOs' interfaces. It is important to consider the consistency of the LOs' interfaces when creating and combining LOs.

II.14 Keep metadata on interface design: All data generated during this phase should be used to create standard metadata, e.g. IEEE-LOM

Phase III. Development

This phase is aimed at producing digital LOs and storing them into a repository.

This phase generates the following outputs:

a) Digital LOs

b) LOs stored in the environment database

This phase encompasses the following procedures:

III.1 Search for LOs in the environment DB or on the Web: One can still mine the Web to look for possible LOs for reuse as components.

III.2 Build the LOs: LOs can be created, reused or repurposed. LOs can be created using authoring tools, such as Dreamweaver, Photoshop etc. One should also use search engine tools, collect text, graphics, photographs, video and audio clips to create digital files, observing copyright laws. To reuse and repurpose LOs found on the Web, assembling tools are needed.

III.3 Perform quality control: This includes the review of design and editorial standards, as well as a functional review.

III.4 Store LOs in the environment database: The database is the LO repository in this case. The policies and procedures of the environment should be complied with.

III.5 Keep metadata: Metadata on technical aspects will be issued in accordance standard metadata, such as the IEEE-LOM

Phase IV. Implementation

This phase is aimed at delivering the instruction to the user.

This phase generates the following outputs:

a) LOs within a LMS or a Web page for delivery

b) Management Plan for instruction delivery

c) The actual Delivery of LOs to the users

This phase encompasses the following procedures:

IV.1 Select a strategy to integrate LOs into a product: One can choose among wrappers, frames, links and templates. One could consider choosing among different LMS environments or delivery the instruction via a Web site.

IV.2 Choose the most adequate delivery mode: One should consider whether learning is best accomplished in a self-paced or collaborative or instructor-led fashion.

IV.3 Create a management plan: One should plan for the most effective delivery of instruction. This is particular important for instructor-led delivery. For self-paced some means of obtaining feedback should be established.

IV.4 Run the product according to the selected delivery strategy: After choosing the most adequate delivery mode, the LOs should be integrated into the proper environment and finally run.

IV.5 Track progress: One should monitor if the plan is being accomplished.

Phase V. Evaluation

This phase is aimed at measuring the adequacy and effectiveness of the instruction delivered.

This phase generates the following outputs:

a) LOs adjustments or deletion from the repository

b) Changes to specific attributes of LOs

c) Verification if instruction is meeting learning goals

This phase encompasses the following procedures:

V.1 Conduct *formative* evaluation: This type of evaluation is carried out before instruction takes place. One can try out LOs on a selective group prior to their delivery and make adjustments accordingly.

V.2 Conduct *summative* evaluation: As part of LOs, there are pre and post assessments that will determine if the learner is meeting the learning goals. One should also consider the impact the instruction is having on the institution vis-à-vis its mission and strategies. One should consider whether learning is best accomplished in a self-paced or collaborative or instructor-led fashion.

Based on the evaluation done, the LOs should be updated accordingly.

5. TESTING THE METHODOLOGY

The first version of the methodology without the LO approach was used in a course given by PUC-Rio to about 40 employees of a public Brazilian company. They were organized into 10 groups and each group had to design and implement an e-Learning module. We found that they had no difficulty in applying the principles and procedures prescribed by the methodology and modules of good quality were produced.

The methodology proposed in this paper enhances the first version mainly with the emphasis on the LO paradigm. This new version was tested in another course given to K-12 teachers and employees from the human resources department of private companies.

So far, the following results were observed: Although each teacher may have his or her own style, they found that, a method to systematically plan instruction is really helpful to guarantee that learning needs are met. They also realized that the possibility of repurposing and contextualizing LOs was extremely important. They found no difficulty in applying the procedures proposed by the methodology, except for the use of authoring tools, such as Flash and Photoshop, to create the contents of LOs. They found that this skill would require more training from them. In general, they considered that it was relatively easy to follow the methodology but they were a bit confused about using the metadata standards to describe the LOs that they produced during the course. They are now looking forward to integrate the LOs produced during the course into their daily activities.

6. CONCLUSION

In this paper we have shown that the development of contents for e-Learning can well benefit from the ISD approach, mainly when it incorporates the Learning Object (LO) paradigm.

We proposed a methodology to design e-learning contents based on the ISD and LO technologies. The proposed methodology can be considered eclectic since it is grounded on principles from behaviorism, cognitivism and constructivism.

Furthermore, it suggests how LO chunking and sequencing could be done based on sound pedagogical principles.

Additionally, the proposed methodology brings more detail to all boxes of the old ADDIE model, while others generally focus on the Design Phase.

This work, which is also a contribution to the PGL Project, is still underway in the Database Technology Lab (TecBD) at PUC-Rio.

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