LEARNING THEORY AND INSTRUCTIONAL DESIGN USING LEARNING OBJECT

Lúcia Blondet Baruque
lbaruque@inf.puc-rio.br
PUC-Rio
R. Marquês S. Vicente, 225, RJ
Brazil

Rubens Nascimento Melo
rubens@inf.puc-rio.br
PUC-Rio
R. Marquês S. Vicente, 225, RJ
Brazil

ABSTRACT

Instructional System Development (ISD) is a set of procedures for systematically designing and developing instruction. A solid foundation in learning theory is an essential element in the application of ISD. One question that one might ask is if there is one best learning theory for instructional design using learning objects (LOs). Depending on the learners and situation, different learning theories may apply. We do not recommend one particular theory for the design of instruction based on LOs. We, rather, suggest the adoption of an eclectic approach to learning theory in the design of instruction using LOs. In this work, we give an overview of the ISDMELO methodology which incorporates principles from different learning schools. The proposed methodology is currently being tested by K-12 teachers from public schools as well as instructional designers from private companies in Brazil.

KEY WORDS

Instructional Design; Learning Object; Instructional Systems Development, Learning Theories

1. INTRODUCTION

The future of educational technology is now calling for the revisiting of traditional instructional models [1]. The fundamental concept is that the same instructional content may be usable in different instructional contexts. Therefore, instructional content designed as context-independent chunks in an object-oriented programming environment can be shared with other users, recombined with other objects, or redesigned by other instructional developers with reasonable expectations of time and cost savings.

In our previous work we focused on the structural aspects of LO [2]. We proposed that a methodology based on ISD incorporated the LO paradigm. The idea was that we should have a systematic approach to developing instruction rather than an *ad-hoc* one. ISD is rooted in the Information Systems area, although applied to the educational arena. Similarly, the object-orientation paradigm, which also originates from the Information Systems area, is now being used in the educational area. This allows for modularity and reusability of educational contents. This is the "object" aspect of the LO paradigm. The other aspect – "learning" – is now the main focus of this work. This means that a LO should have the right semantic of learning. A thorough understanding of what is "learning" becomes crucial. To this end, it is imperative that a methodology to design educational contents based on LO be grounded in learning theories.

Depending on the context and the audience nature, a more general approach seems to be more useful than a specific one. We propose an eclectic approach to learning theory so that pedagogical principles from different learning schools can support the methodology. Our experience with the PGL project, where our audience encompasses a variety of profiles of users reinforces that an eclectic approach to theory seems to be more adequate. As stated in [3] learners have different orientations: they can be transforming, performing or conforming learners. This requires different strategies, therefore an eclectic methodology could be considered the middle path between standardization and personalization.

PGL (Partnership in Global Learning) is an international initiative to design and produce e-Learning contents for the corporate, academic and consumer market on a global scale [4].

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 [5]. 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 [6]. 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. But on what basis these decisions should be made? Learning theories describe how learning occurs while instructional theories prescribe the best way to design instruction to foster learning [7]. Different schools prescribe different strategies, but we believe that all have valid principles, which are applicable to LO.

This work aims at proposing an eclectic approach to learning theory in the design of instruction for e-learning modules. To this end, we show how principles from different schools were incorporated in the Instructional Systems Development Methodology based on e-Learning Objects (ISDMELO). This methodology is aimed at the design and development of educational content to be delivered via the Web. We use a top-down-model approach where we find pedagogical dimensions in different layers of abstraction. This model is useful to show how our methodology is grounded in sound pedagogical principles. This methodology is being developed in light of the requirements of the PGL Project. As part of this project, a multimedia e-learning oriented distributed database system is being developed to serve as a LO repository in the PGL environment [8].

The remainder of this paper is organized as follows. In Section 2, we mention the importance of the fundamental of learning theories for the design of instruction based on LO. Following this, Section 3 gives an overview of the ISDMELO methodology with its phases, outputs and procedures. Section 4 shows how pedagogical principles from different schools are included in the ISDMELO methodology, thus emphasizing its eclectic nature. 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. THE IMPORTANCE OF LEARNING THEORIES FUNDAMENTALS

In this section we give a brief description of three major learning schools and present a top-down-model, which helps in the analysis of the application of pedagogical principles in our methodology.

2.1 The Three Learning Schools: Behaviorism, Cognitivism and Constructivism

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 simple 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* one 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 the mental processes of the student.

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.

In [7], we find a suggestion on the application of each school principles which considers the learner's knowledge level and the complexity of the subject to be learnt.

Although Figure 1 presents some criteria for the application of learning theories, we believe they are not mutually exclusive. For example, an instructional designer may define clearly an expected behavior from a learner (*behaviorist* perspective) while she can establish a group activity or problem-based activity (*constructivist*

perspective) where the learner will practice the knowledge acquired.
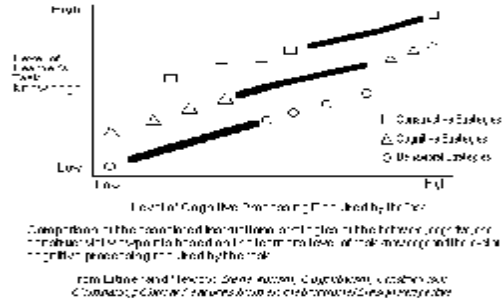

Figure 1 - Application of Learning Theories

2.2 Learning Theories Framework

As mentioned before, a sound methodology for designing and developing e-learning modules should be grounded on principles from important learning theories.

In [9], a top-down-model is described in which pedagogical dimensions are imbedded in different layers of abstraction. See Figure 2. The 4th (highest) layer of abstraction is often referred to as paradigm or as way of teaching, learning, thinking and designing. Behaviorism, Cognitivism and Constructivism are major approaches. The 3rd layer of abstraction can be considered as a set of underlying principles. The 2nd layer of abstraction contains instructional models and theories which are guidelines or a set of strategies. The 1st layer of abstraction contains content, practices and activities. This layer describes what is done and to be learned as well as which resources are actually used.
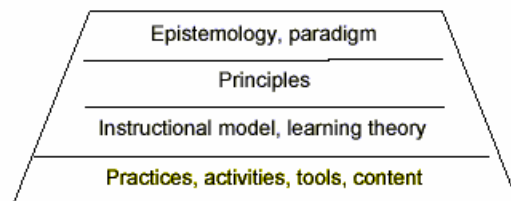

Figure 2 – Top-down-model

The top-down-model makes it clear that any decision which is made at a higher level of abstraction affects the more basic levels. So, our objective is to show that the instructional strategies and practices recommended by our methodology are grounded on sound pedagogical principles, following the top-down-model. In order to make it clear, the tables found in Section 4 show examples of its application.

3. A METHODOLOGY TO DEVELOP e-LEARNING MODULES BASED ON LOs: ISDMELO

In this section we present a summary of the ISDMELO methodology [2], which is based on the general method named ADDIE, which includes the following phases: Analysis, Design, Development, Implementation and

Evaluation [10]. It is important to mention that it is oriented to a by-hand assembly of learning objects by an instructional designer.

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 analyzing 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 [11] is 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 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 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 [12]. 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 [13]. 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. It should be noted that this approach to sequencing allows learner control what is in line with the constructivist perspective since the learner is not supposed to follow pre-requisite sequences which may be boring to him.

II.5 Categorize LOs: After identifying the LOs, one should now assign a category type to them. We use the one proposed in [14] and [15]. 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. At this point, it is important for the instructional designer to consider the context in which the LO will be used. If it is under the constructivist perspective, the LO should not be tied to a specific learning objective. The learner would establish

his own goals dynamically. For example, when using a LMS, the system could hold different learning objectives from which the learner would choose a specific one.

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.

4. HOW ARE PEDAGOGICAL PRINCIPLES INCORPORATED IN THE ISDMELO METHODOLOGY

In our previous work [2], we presented a methodology where we emphasized the advantages of using the Object-Orientation paradigm, specifically LO in an ISD methodology. As mentioned before, we believe that such methodology should be grounded in sound learning theories. In addition to the structural aspects of the LO approach to instruction design, let us look now into the "learning" aspect of LO. To this end, we examine how the three basic learning schools (*Behaviorism, Cognitivism, and Constructivism*) influence the proposed methodology.

4.1 Behaviorist Aspects

Considering the top-down-model presented above, we verify the following *behaviorist* aspects:

Highest Layer	Behaviorism
3rd Layer	Learning is inferred from behavior; it is important to identify the goal behavior
2nd Layer	•Gagné´s Learning Hierarchies Theory
Basic Layer	•Definition of learning objectives by the teacher or instructional designer •Task/Content Analysis • Feedback •Pre and Post Assessments

4.2 Cognitivist Aspects

Considering the top-down-model presented above, we verify the following *cognitivist* aspects:

Highest Layer	Cognitivism
3rd Layer	Learning is described as a change in knowledge stored in memory
2nd Layer	•Elaboration Theory •Information Processing Theory
Basic Layer	•The use of advance organizers •Capacity of the short and long-term memories •Content chunking into meaningful parts

4.3 Constructivist Aspects

Considering the top-down-model presented above, we verify the following *constructivist* aspects:

Highest Layer	Constructivism
3rd Layer	Learning is a change in the meaning constructed from experiences
2nd Layer	•Problem-Based Learning
Basic Layer	•Definition of learning objectives on a dynamic way, as goals established by the learner • Learner control, since the sequencing does not force a pre-requisite sequence to be followed •To pose good problems to students •To use collaborative activities

In summary, 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 [13]. 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.

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 focused on the "learning aspect" when including the LO paradigm in an ISD-based methodology for the design of e-learning instruction. Our concern was with the LO semantic which is better expressed when the design of instruction is grounded on sound pedagogical principles.

Our methodology does not follow a constructivist perspective, but incorporates elements from this school. For example, it is flexible so that a LO may have as an attribute a behaviorist learning objective or a constructivist goal established dynamically by the learner. It also permits some learner control on the sequence of instruction and the use of collaborative and problem-based practices.

We proposed that an eclectic approach to learning theory be used when designing LOs, so that valid principles from each school can be taken advantage of in face of a broad target audience.

We also showed, using a top-down-model, how the different pedagogical dimensions are embedded in the proposed ISDMELO methodology. The idea is that principles from each of the major learning schools (*behaviorist, cognitivist and constructivist*) can be combined in creating and sequencing successful e-learning modules based on LOs.

We believe that the main value added by our work relates to the human assembly of learning objects. Many researches in the literature are oriented to the LO automated assembly. However, the majority of data available on the public Internet are learning contents that do not easily fit into automated systems [16]. In order to achieve a a greater educational impact with LOs we have to consider their manual reuse. The aim of our methodology is to guide instructional designers in the production of e-learning contents while reusing available LOs and generating new LOs to be reused by others.

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

7. ACKNOWLEDGEMENT

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