Development of learning objects for the support of product design and manufacturing processes knowledge construction.

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***Abstract* - This paper reports some ongoing experiences and partial results of a research related to the use of the learning objects concept in disciplines at the Production Engineering undergraduate course at Federal University of Juiz de Fora, Brazil. The research can be folded in two directions. The first is the learning objects development itself that aims to build a database of virtual objects related to basic engineering and technology contents. This learning object construction is also related to some previous experiences in the development of web based environments for product design teaching and learning support. The second direction is the evaluation of the use of those learning objects in classroom's and in computer labs with basic and applied engineering contents such as materials engineering, product design and manufacturing processes. This evaluation is being structured in the moment from a qualitative approach. However, the initial tests made in some classrooms in the end of the last semester showed a great interest from the students side.**

Index Terms - Learning object, Web based environments, Product design, Manufacturing Processes.

INTRODUCTION

The computer and information technology resources available nowadays for all knowledge fields and especially in the technological and engineering areas are expanding the possibilities of new educational methodologies and media. Also the growing number of students with access to computers and to the Internet is demanding a significant effort in research and development of computer based learning systems and methodologies. In the context of Brazilian engineering courses there are some efforts in this direction. However it is clear that still there are many open fields of research to be addressed. In this way, one of the most important tasks is the development of reusable learning objects. Another direction is the development and use of web based environments to provide a framework for specific engineering contents and its learning objects that can be recorded and catalogued in an organized and easily accessible way.

This paper reports some ongoing experiences and partial early results of a research related to the use of the learning objects concept and its storage on a web-based environment entitled Design Knowledge Database (DKD). This environment was previously decrypted in a paper on the ICEE 2005 conference [6]. Those learning objects are now starting to being used in disciplines such as Product Design and Manufacturing Process. The main target of the research is to build a database of reusable learning objects to support the classroom activities on those disciplines. To ensure that those objects will be used more efficiently as possible, the research team is following some design strategies that are decrypted in the paper among with theories on learning objects development that supports the research. In the end there are some considerations on the early results and the directions for the research continuity.

LEARNING OBJECTS

In a broad sense learning objects can be defined, according to IEEE/LTSC, as a virtual or physical entity that can be used and reused during a learning process [8]. More specifically those objects can be considered as small self-contained units of information or instruction. They can be developed trough the use of many different digital media types and may be flexibly combined to form content packages of different knowledge areas [1].

In a traditional approach, most of the instructional content is developed to fill some specific need such as, for instance, the concepts of a manufacturing process. Reusable learning objects, on the other hand, are instructional software modules created to be used in a variety of educational settings.

According to Wiley [11] the concept of learning objects is grounded in the object-oriented paradigm that came from computer science. The fundamental idea is that educational media designers or even teachers can build components that are relatively small, compared to the length of an entire course, and share it in order to be accessed and used many times as required and also can be allocated in many different contexts as needed. Also as stated by Wiley [11] and other authors, learning objects are generally understood to be digital entities deliverable over the Internet, meaning that any number of people can access and use them simultaneously.

Then one can see that those objects can be designed to be a variety of digital media such as texts, hypertexts, still images, animated images, videos, interactive scripts or software's. Also the learning object is frequently a combination of two or more of these media types. Generally they are developed with a focus in determined content and stored in database from where it can be accessed to compose a set of educational media with a specific target for the context in hand (figure 1).

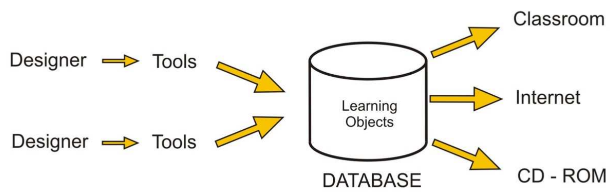

FIGURE 1
DIFFERENT TOOLS AND CONTEXTS FOR LEARNING OBJECTS

STRUCTURE AND DESIGN OF A LEARNING OBJECT

According to Merrill [6], the design of learning objects requires the definition of what it will be and the organization and storage of them in electronic databases. In order to the user easily access those objects in a database; they must be tagged with predefined characteristics. There are many approaches to that kind of organization of technological knowledge [4]. One example is of a possible tagging scheme is presented in Table 1.

TABLE 1 – ADAPTED FROM [6].

Object class	Definition	Examples
Domain	Refers to general subject matter or discipline.	Mechanical Engineering
Subject	Specific topic within the domain.	Mechanisms
Content Type	Types are defined according to some classification scheme.	Fact Concept Procedure Process Principle
Instruction Element	Refers to the instructional function played by the knowledge object.	General exposition Example Analogy Practice Solved Problem Assessment
Media Type	Refers to the technical means by which content is displayed.	Hypertext Still Picture Animated Picture Sound Track Video

The design and development stage of a learning object starts with the definition of objectives and the context of application. The designer must bear in mind that the user, a teacher for instance, will select a set of objects developed for a determined subject to build some specific content for his purposes in a discipline or for a conference in other occasion. In this object oriented approach, the designer must know the functionalities of the database in use to design, select, organize and connect the objects.

One of the positive arguments for the use of leaning object is the time saving that is possible for the user. The teacher would have no need to neither do extensive research on the subject matter nor develop the material [1].

In that sense, a successful design begins with a user needs identification to determine what knowledge or skills are required by the learner. This may include a task analysis to distinguish critical information and learning prerequisites. The designer can then use this information to create individual learner objectives. Often, the designer will design a separate learning object for each discrete objective. This is a typical approach in the product design process.

According to Clark [5], individual objectives should be classified by learning types such as concept, fact, principle, or procedure as viewed in table 1. This approach allows targeting of optimal design strategies to different types of instruction. Individual learning objects can then be grouped together to address specific real life tasks, and a design specification can be created to guide development.

Designers of learning objects can use almost any development tools available nowadays to create digital media, including PowerPoint, Photoshop, HTML and Hypertext builders, Flash, or custom creation tools. It is also frequently the use of two or more kind of files to create one individual learning object. So the designer always uses texts, graphics, still and animated images, videos and other content that can be combined in only one object.

LEARNING ENVIRONMENTS: THE DKD

The integration of a previous developed learning environment – the DKD – with the concept of reusable learning objects is now being experimented. The results from the utilization of the DKD with students of the Product Design discipline showed significant results and are now enhanced with the utilization of learning objects contents. In fact the DKD was previously developed as an environment to enhance the teaching and learning processes of product design and not though as a database for learning objects.

As reported in [7], the DKD is structured around three main modules that are connected by an association's tool. The first module is related to the explicit knowledge incorporated in the design activities and is represented by a dynamically constructed database. It can be constantly improved by the contributions of the users. These contributions can be uploaded to the system by anyone that access the system. The second incorporates a case-based library related to the implicit knowledge that came from the user's experiences and also from the design tasks that are being developed by the students or teachers. It can be dynamically constructed in the same way as the first module. The third module deals with the implicit knowledge that came from the association of case based library and projects in development with the personal knowledge of each one that is involved in the design process. It intends to capture this kind of personal knowledge allowing the user to formalize how some specific task can be done or how to perform some procedure related to, for instance, what the team is doing in the moment. This module can also keep some registers of methodologies and practices of the product development that can't be classified in a more formalized and classified way in the first module.

Those three modules are linked and articulated by the resource of association of contents. This means that a recorded file in the explicit knowledge data base can be associated and linked to a specific file of a design step in the sample library module or to a description file in the procedures module. All contents in all levels can be associated.

Each module is organized in levels in order to structure the technological knowledge in a way that is familiar with the kind of work of engineers and designers. For a sample of this organization one can take as example the information and knowledge available that are related to some mechanical concepts that can be incorporated on a product or component of it. The hierarchic structure for the connecting rod and crank basic principle is presented bellow:

- Engineering Fundamentals (1º. Level).
  - Mechanical Technology (2º. Level).
    - Machines (3º. Level).
      - Mechanisms (4º. Level).
        - Connecting rod and crank (5º. Level).

This structure developed for the DKD [2] is similar to the presented in the table 1 [5] and the experience on its use is showing that this is a good frame work for learning object organization and storage.

The figure 2 shows a fragment of the DKD interface with a fifth level content sample of the structure mentioned above. In this case one learning object (linked hypertext) of the connecting rod and crank principle is showed and one can see that is possible for the user to post some comments about the content displayed in the window left frame.

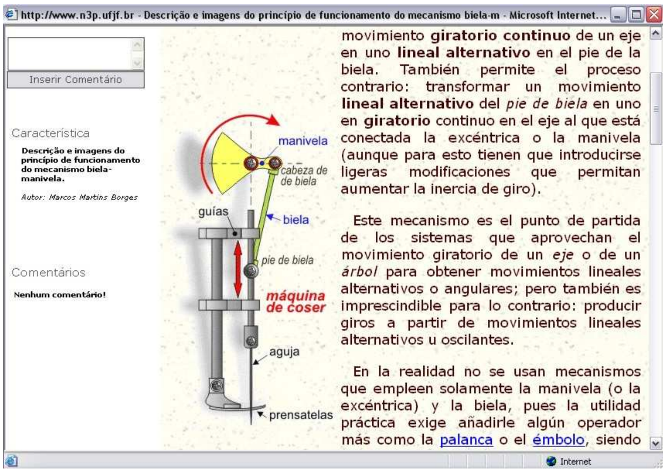

FIGURE 2
SCREEN CAPTURE OF THE DKD

It is allowed to the users the registration of new contents and it can be recorded according to the design languages types (semantic, graphical, analytic and physic) as is pointed by Ullman [9]. In a practical point of view these language types are represented by text files, raster and vector images and some more complex three-dimensional files customized for web viewing. This is one of the interesting features in the DKD environment. It allows the possibility for storage of diverse kind of file formats allowing the students and teachers to record almost any kind of digital information related to the task in hand, including a organized set of learning objects.

The DKD can be accessed trough the following address: www.n3p.ufjf.br/bcp. It is necessary to fill a registration form to have access to the system.

REPORTS ON THE ONGOING EXPERIMENTS

The experiments took place in the computer lab of the Production Engineering course at Federal University of Juiz de Fora. This lab has twenty computers available for a class of about eighteen to twenty two students, one computer for the teachers use and one server that hosts some of the systems developed. All computers are connected to the Internet. There is also a digital projector and an overhead projector. The activities are being done in the Product Design I of the sixth semester of the course in the second semester of 2006 and now in the first semester of 2007 (still in course). Also some experimentation is now taking place with the Manufacturing Processes discipline in the seventh semester of the course.

In the Product Design I discipline the theoretical concepts of design methodologies are approached and intend to give to the students an initial and broad sense of the nature of the design process itself along with a more detailed study of the main steps of it. These are the identification of customer needs, establishing the scope of the project, listing the basic specifications from the user's statements and necessities, decomposing the problem and generating solution concepts for each sub problem, select and synthesizing a concept to be developed, refine the specifications and detailing the product. Those contents are based on a book named Product Design and Development [10] used as the text book of the discipline. Along with those design process contents there is introduced the topics related to the simple machines, mechanisms, basic electronics, structural systems and materials [3].

In both disciplines the experiments are organized in three steps. From an initial presentation of a specific concept by the teacher, the students organized in groups, are assigned to perform three tasks related to the use of learning objects. In the first step they must search educational objects available over the Internet and made a brief presentation of it. In the second step they must design and develop some simple learning object related to the same concept searched previously. This development could be from scratch or the customization of an existing one. In the third step the students have to record the objects in the DKD and make some associations between the objects and the knowledge stored in the system.

In the case of the Product Design I discipline the concept used to perform the experiments was the connecting rod and crank mechanism. This concept is part of introductory overview on simple machines, mechanisms and how they interact in a complex machine. These concepts also acts as a background in how are the functioning principles in the more complex operating machines worked in the Manufacturing Processes discipline.

The student's teams were able to find a huge amount of digital media trough the Internet related to the connecting rod and crank principle. They range from simple still images associated with explanatory texts in an HTML document to very well developed animations explaining the concept. For the first step those files were catalogued and organized for the storage asked for the third step.

In the second step some teams choose to develop a learning object from scratch and others to customize some of the founded early. It is important to emphasize that the design and development done was according to the design methodologies concepts studied in the Product Design I discipline. This means that they must have a structured approach to define how the object will meet the user's needs. In this case the students itself.

In the third step the storage was made under the orientation and interference of the teacher in order to allow a precise fit of the files in the database structure. Actually the DKD permits the storage by the students. Later the teacher as an administrator of the database can edit the record and choose the better organization when it is the case.

In the Manufacturing Processes discipline the teams followed the same procedures and there were found and developed some good samples of learning objects. For instance, one team chooses to work with the drill press process basic concepts. This project is still under development but seems to bring some good results. For that example they are using a drill press available in the manufacturing processes lab and are developing the work in two parts. One is the design and development of a digital learning object using still and animated images of the drill press functioning concepts inserted on an HTML document. The second part is the design of a poster that will be fixed besides the drill press in the lab.

In the end of the semester the students teams must make a presentation of the concept and object developed and fill a form with some questions about the experiments realized. These questions intend to give some initial feedback about the experiments and are now redirecting some procedures.

Some student's research and work lead to the use of specific software to model and simulate the behavior of simple machines and mechanisms. The most interesting program found was the Working Model (Figure 3).

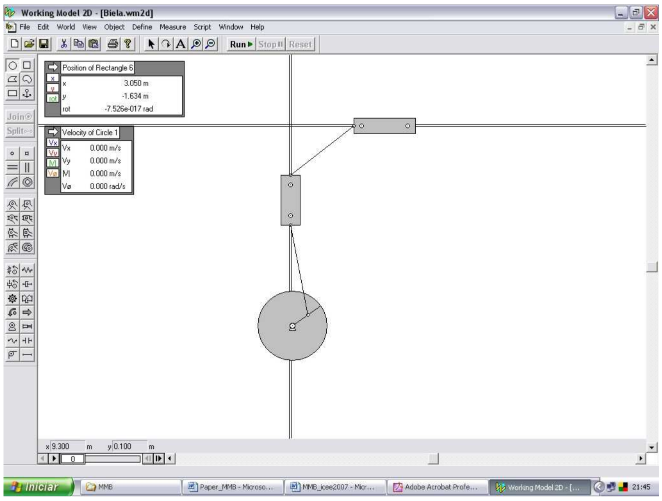

FIGURE 3
SCREEN CAPTURE OF THE WORKING MODEL 2D PROGRAM

This software was used in the demo version and the Production Engineering Department at UFJF is now evaluating this and other options aiming to purchase a license. Although the use of such program seems to have a positive impact among the students, there where some problem related to the difficulty to make the objects developed available on the Internet. The files generated by the program can be stored in the DKD but anyone that wants to work with it must have the program installed in his computer. The students modeled with ease the concept of the connecting rod and crank mechanism in the program, but the only way they found to share it was trough a video file or a still image. However it showed a great potential and will be used from now besides the other kind of tools do produce learning objects.

One of the future trends in the research reported here is the use of physical learning objects as an artifact possible to interact with the virtual objects in various levels. In that sense, as the learning objects can be considered as almost any digital media that can enhance the learning of some specific concept, there is a huge set of possibilities of interaction among physical and digital objects. Initially the links that are being tested are simply descriptions of concepts and procedures that can be accessed from a computer besides the physical device in a lab. With the development of the research they are being transformed in more dynamic and interactive relations that are made possible with the use of devices such as digital cameras and various kinds of sensors.

FINAL CONSIDERATIONS

The fact that the students are assigned to develop some simple objects seems to enhance their ability to understand the basic functioning principles incorporated on it. This allows them to have a critical view over the existing objects and incorporate functionalities or information that there where not available. Also the level of interactivity incorporated in a learning object is of significant importance on the effectiveness of its use. The use of interactive software (Working Model) to build the knowledge about some technological concept is the activity that has the major impact on the student's preferences.

According to [1], there are many aspects that must be addressed to a more efficiently use of learning objects. One of the most important is the reusability and availability of them in a well organized database. The use of the previously developed DKD seems to be a good choice for the moment. This is important if the context and physical facilities of the Production Engineering course at UFJF are considered.

There were diverse arguments enhancing the benefits of the learning objects use in the teaching and learning processes in various knowledge fields. Some of them advocate the following according to [1]:

- Reduced development time and cost.
- Easily accessible when needed.
- Reusability.
- Use of accessible tools to develop.

However, there are some issues that have yet to be addressed by designers of learning objects in order achieve better results. Among these are the following:

- Achieving truly free-standing knowledge objects;
- Develop learning objects that can be accessed from multiple platforms;
- Establish a standard for knowledge tagging;
- Design learning objects that brings up the contextualization of content.

Finally, the experiences and the research in progress reported here are going in the direction of some of those issues and other directions were identified that needs to be addressed. One of the most important issues is related to the contextualization of the content. This seems to be a very significant task to be achieved by designers and instructional developers. Without this contextualization is possible to the learning objects don't fit its fundamental purpose: the knowledge construction. For the work being developed and reported here there are some significant tasks to be undertaken. One of the most important is the evaluation of the developed learning objects from a qualitative and quantitative approach. These tasks are configured as the next step in the research.

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