ADVANCES IN TECHNOLOGY-BASED EDUCATION: TOWARDS A KNOWLEDGE BASED SOCIETY

Proceedings of the II International Conference on Multimedia and Information & Communication Technologies in Education

m-ICTE2003

www.formatex.org/micte2003/micte2003.htm

Badajoz, Spain, December 3-6th 2003

Edited by

A.Méndez-Vilas
J.A.Mesa González
J.Mesa González

ISBN **Volume I**, (Pages 1-658): 84-96212-10-6

ISBN **Volume II**, (Pages 659-1335): 84-96212-11-4

ISBN **Volume III**, (Pages 1336-2026): 84-96212-12-2

Published by:

JUNTA DE EXTREMADURA,

Consejería de Educación, Ciencia y Tecnología (Badajoz, Spain), 2003

Printed in Spain

VIRTUAL EXPERIMENTS AND LEARNING OBJECTS FOR SCIENCE LEARNING BASED ON VIRTUAL SCIENCE CENTERS AND MUSEUMS

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Our aim is to describe and define virtual experiments, as a mode of complementation for real experiments in science learning, as well as to explore its potential for complementing informal learning activities carried out by science museums and interactive science centers in the digital domain. Specifically, virtual experiments can lead to inquiry learning and open ended investigation in opposition to the closed and out of context "hands on" experiences supplied by science centers. The application of the learning object concept to this kind of resources, with the adoption of standard description and educational metadata, can provide for better resource discovery and utilization in behalf of the formal sector of education, and for the establishment of an rational economic basis for resource sharing between virtual science museums and science centers gathered around thematic or geographical networks.

1 Introduction

The concept of virtual experiment is related, in the science-technology system, to the concepts of "co-laboratory" or "virtual laboratory", activity support tools for remote scientific collaboration [16, 6] and with the virtual science paradigm, as an extension of the traditional scientific method, in which simulations can generate new scientific knowledge [20]. Meanwhile, virtual experiments can also be applied to the education field, with the purpose of transmitting or communicating it to the target public.

On the other hand, the virtual museum, understood as a collection of logically related digital objects, has its great differential in the capacity to provide authentic multimedia experiences in its domain, but without aspiring to the authenticity of the real object, that by its own definition cannot be fully mediated. Particularly, it can stand out in relation to the traditional museums exactly by what it may be its main characteristic: virtuality. In this manner, virtual experiments arise as a natural and unique kind of content, as a way to extend the educational experiences of those institutions dedicated to create knowledge stimuli to their visitors which are conducive the understanding of the scientific method, so that they can function as actors in the objective of promoting the relationship between knowledge acquired in formal education and in the daily and professional life.

2 Theoretical background

For Carnevale [4], the question related to the adoption of virtual experiments in educational settings presupposes a paradigm shift, from information transfer to its acquisition, as in the inquiry spirit which should be present in virtual laboratories.

In this discussion, there is a need to understand more precisely the differences between the physical and informational economies of both types of laboratory. The real laboratory is used to relate fundamental science concepts to real world phenomena, to reinforce learning through experimentation, and to propose problem solving with a practical sense. Its pedagogical deficiency resides, in the meantime, in the necessity of time-space shifts between what is taught, explained and learned, and what it is practiced and internalized. Furthermore, they require costly and difficult to obtain physical space and resources and efficient logistics, in order to support the physical laboratory setting [22]. In addition, traditional activities in laboratory are designed to reduce uncertainty, demand little engagement by the students and do not emphasize social interaction [9].

The essence of virtual laboratories, on the other hand, is its informational value, the learning and the "*hands-on*" experiences that they provide, at the same time freeing educational value from the limitations provided by physical and economic factors. For example, by using digital simulations instead of physical contraptions, virtual laboratory experiments have the capacity to accommodate an unlimited number of simultaneous experiments. Furthermore, virtual experiments can also be used to simulate dangerous environments (such as the inside of a nuclear reactor), activities which are too expensive or that require extensive training or technical skills (such as anesthetizing and operating a live animal), as well as situations which would be impossible to be observed in the real world, such as those that can only occur in extreme microscopic or macroscopic settings (e.g., observing the wave-particle behaviour of electrons) or that that take too long to happen (such as observing the collision of two galaxies).

Conceptually, virtual experiments deal with the convergence between what it is taught and what can be simulated, observed and practiced. An important aspect is that virtual laboratories allow to experiment more than what would be possible in a real laboratory, may it be for time and security reasons or by providing more variables than those present in reality, allowing the re-creation of any possible situation [4]. From the teacher's point of view, supervision in the laboratory changes from assuring the students´ security towards assuring that educational objectives are met, for example, by evaluating the experiment's feasibility, students´ motivational level and learning's achievements [14].

At the same time, the study of scientific laws and concepts usually demand ideal conditions, impossible to be met in the real world, so that "the best analog in real world can never compare to the simplicity and elegance of a virtual experiment of this kind" [14]. What's more, virtual experiments allow experiences which go beyond reality; an example is the "Virtual Microscope", developed by Open University of United Kingdom. This virtual apparatus allows students to rotate a rock sample, and visualize it in plane-polarized and cross-polarized light at the same time, an impossible action in a conventional microscope [25].

With respect to the nature of information, virtual experiments and demonstrations are most suitable for representing dynamic information, for example, of chemical reactions or biological processes. In addition, they allow for real interactivity, with system's parameters manipulation aiming for a better comprehension and multimedia representation of concepts, through the study of interactive graphs and animations. All these types of information cannot be effectively represented, distributed or communicated in textual form [15].

In the case of realistic 3D visual environments, such as in virtual reality, these allow for a more faithful visualization of objects, in comparison with 2D models, given the additional depth dimension and the possibility of using multiple points of view. Virtual reality incorporates characteristics of immersion, telepresence, immediate visual feedback, autonomy and interactivity. Immersion helps the retention of information, allows a better memorization of concepts and encourages the use of the virtual environments [2]. Besides, immersion helps the formation of conceptual models, as long as intangible concepts in the real world can be represented in a visible form that in addition, can be manipulated. Additionally, interaction implies an attitude transformation, from passivity towards active thought; on the other hand, engagement with and control of the application provide the affective, motivating aspect. Another argument in favour of total immersion is that it isolates the learners from possible distractions, besides providing a multisensorial experience, with visual, auditory and haptic clues being transmitted simultaneously to the user [24].

In a level beyond visual information, force feedback in haptic interfaces could be a form of engagement with scientific ideas and mathematical symbols. Its areas of application are geometry, mechanics, the study of chemical bonds and gravity, surgical simulations, among others [19].

From a literature review on the subject, it is concluded that simulations can be more effective than other types of computer supported learning. Learning by simulation is generally faster than in traditional instruction and simulations can be more effective for performance improvement. The reasons for this effectiveness are justified by the conceptual change obtained by demanding students to state explicitly their suppositions and implicit reasoning [11]. Other benefits of computer simulations identified in the review are the reduction of the cognitive noise, so that students can concentrate themselves in concepts involved in learning objectives. In the same way, the reduction of realism would allow for the distillation of abstract concepts in its more important components [3]. Simulations also provide ambiguity reduction and help in the identification of cause-effect relationships in complex systems [7] and help in the natural world understanding, through observation and interaction with underlying scientific models that are not easily inferred from direct observation [18].

3 Practical application

Meanwhile, the technical complexities involved in the creation of virtual experiments are one of the main barriers that educators face for their adoption. In order to disseminate the use of simulations, the creation of digital contents must be made easier. Conceptual modelling of "virtual apparatuses" has as the objective of decreasing technical overhead in the design of virtual experiments, allowing for non-programmers to create and modify experiments through a user friendly interface. This vision implies the construction of a generic component of reusable software, based upon open specifications, in order to assure interoperability between apparatuses coming from different sources that could be combined to create new virtual experiments [14].

In this way, we can relate virtual experiments to the "learning object" concept, which constitutes a new paradigm for the development of digital educational materials adopted by technologically supported and distance education communities. Learning objects are characterized by being **reusable**, with the possibility of use in different contexts; **granular**, so that they can be added or divided for the formation of new objects; **interoperable**, with the possibility of use in different platforms; **modular**, so that an object can contain or be contained by other objects and **describable**, by metadata in relation to its contents and didactic use. A possible definition proposes that a learning object is “a digital file (image, movie, etc.,) intended to be used for pedagogical purposes, which includes, either internally or via association, suggestions on the appropriate context within which to utilize the object” [23]. For Wiley [26], the fundamental idea around the learning objects –digital entities distributed through Internet– is the construction of relatively small instructive components that can be reused in different learning contexts. The rationalization for its use is often based on an economy concept. In this sense, the effort to produce many versions of similar objects, as opposed to the shared use of versions of a same object, is compared, with the extraction of common elements from many courses as a mean to reduce expenses in the preparation of didactic materials [8].

The learning object concept is supported technically by the development of educational technical standards, with the coexistence of several organizations like IMS Global Learning Consortium, IEEE Learning Technology Standards Committee (IEEE-LTSC) and the ISO- IEC collaboration through the subcommittee “Information Technology for Leaning, Education and Training” - SC36. Educational metadata standards describe an individual or collections of learning object’s content, meaning, possible uses, structure and behaviour. Fundamental for learning objects is the LOM standard, *Learning Object Metadata*, first *de facto* standard approved in e-Learning.

Technically, sharing and reusing learning objects is accomplished through digital repositories. A repository is defined as a central location in which an aggregation of data is stored and maintained in an organized way [10]. Besides technical questions, repositories trigger questions like quality control, intellectual property management, the distribution of resources through many repositories as opposed to the centralization, the necessity of cooperation and communication between players in order to carry out a cultural change in the educational field, in addition to cultural differences as complementary hurdles, from an international point of view.

In present time, development and continuous improvement of available materials in repositories are accomplished through quality control actions, in the form of peer reviews lead by experts in each thematic area, of awarding systems and of support activities [10]. The many different existing projects adopt their own internal guides for quality control, as a mean to provide a quality standard and its accompanying credibility. In *the Gateway to Educational Materials* (GEM) project, resource selection is based upon a previous evaluation, centered around six key criterions, based on traditional Internet resource evaluation methodologies [13, 27]. Resources are evaluated based on their accuracy, appropriateness, clarity, relevancy, completeness, motivation and organization [12]. Specifically in science education, the *ScienceNetLinks* project, dedicated to increasing credibility and quality of scientific educational content in Internet, as well as to the establishment of trandisciplinary educational experiences, adopts criteria like the representation of science as process, consistency of scientific content in relation to present scientific knowledge and representation of science as an dogma-free open inquiry tool [21].

4 Discussion

Among the questions associated with reusability and shared distribution of educational resources, the adoption of a learning object economy would affect educational institutions, that would dedicate less time in creating resources, and more to activities creation and resources contextualization. The repository concept is close, then, to the “metacenter” concept, or more simply, virtual museums associations. As a common characteristic, all information metacenters share challenges like adding a critical mass of digitized information, to develop and implement standards for museological information exchange [17]. Last, but not least, the metacenter would be related to the distributed museum concept, the digital interconnection of all the museums of the world, where “each museum is potentially all museums” [5]. The main function of the metacenter would be one of an easy to use central device, improving access to information, with the purpose of jointly creating rich and complex reserves of information and extending the reach of each individual museum, with a greater opening to the public and a greater potential audience [1].

Thus, we close a cycle, with the observation of a convergence between learning objects digital repositories and virtual museums metacenters, through a possible common denominator, virtual experiments. We believe that such a convergence arises as a way to boost the science museum’s educational mission, relating them in a more explicit way to the formal educational system, main user of digital repositories. Furthermore, the same educational conception contained in the learning object definition demands that these institutions reflect upon their objective of helping in the understanding of science, more than simply amusing visitors. In a related way, virtual experiments also suppose an approach to active and inquiry learning, with the providing of a personal discovery context, often absent in real museums. For repositories, on the other hand, the main contribution of virtual museums would be the offering of educational resources provided with quality criteria, besides the recognition of reliability, authority and impartiality on the behalf of the public.

This so-called convergence also fulfills a strategic objective, making possible an economy of resources and institutional collaboration, especially important for those less economically equipped institutions. In conclusion, we believe this convergence comes up as an opportunity for all the community, in one or another way related to science education, to tie stronger bonds and improve its methods and achievements. Our future research will investigate not only technical standards and protocols for virtual science museum learning objects and virtual experiments sharing, but also the necessary social and institutional mechanisms for the establishment of efficient collaborations. Lastly, we are interested in the possibility of integrating digital and real objects in the exhibitions, through technical standards for educational designs, particularly the IMS Learning Design specification, based upon the Educational Modelling Language (EML).

5 Acknowledgements

Our thanks to Dr. Miguel Ángel Quintanilla for supporting this research inside the Novatores Project framework, which is financially supported by the Junta of Castile and León (Spain); also my thanks to Dr. Joaquín García Carrasco for helping me develop the conceptual framework of this research and to Dr. Renato Sabbatini and Dr. Betania Maciel for the critical review of this manuscript.

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