COLLABORATIVE LEARNING IN A VIRTUAL REALITY ENVIRONMENT

Liane Tarouco and Rosa Maria Viccari
Federal University of Rio Grande do Sul (UFRGS)
Porto Alegre - RS - Brazil

Marlise Geller
Lutheran University of Brazil (ULBRA)
Canoas - RS - Brazil

Luiz Fernando Tavares Meirelles
Catholic University of Pelotas (UCPel)
Pelotas - RS - Brazil

ABSTRACT

3-D virtual environments for online learning may be considered a second generation of software for distance learning support and allows learning by doing. The construction of these environments with both proprietary and open technologies was the object of the work related in this paper. Methodology and processes used in the creation of 3-D objects and in the development of a collaborative learning environment software using virtual reality are presented as well as some details about implementation. A virtual tutor based on chat technology is also part of the designed and implement virtual laboratory aimed to support collaborative learning.

KEYWORDS

Virtual reality, collaborative environments, artificial intelligence, distance learning.

1. INTRODUCTION

We are living now in a digital era of learning. Transformation in learning is taking place from "broadcast" learning to "interactive" learning. No longer are today's generation of learners satisfied in being the passive recipients of the traditional teaching process, rather, they want to discover it for themselves by becoming interactive with the learning. Though, how successful technology-mediated learning activities will be at facilitating higher order thinking skills will be dependent upon the approach taken to the design, delivery, selection, and utilization of appropriate and effective technologies with a support structure to maintain and sustain the learning transactions. Recent advances in information technology have made it feasible to employ distance learning systems in support of the growing demands for educational services. Unfortunately, it is difficult for present distance learning systems to deliver the 'hands-on' learning environment that a well equipped laboratory provides. Virtual Reality may be used to allow the distant student to access an interactive virtual laboratory. It is important to note that a VR system is essentially an interactive simulation that can represent a real or abstract system. The simulation is a representative computer based model which provides appropriate data for visualization (could also include auditory and haptic/kinaesthetic) or representation of the system in a virtual world.

Virtual Worlds are real or imaginary buildings that can be emulated with the use of computational resources applied to the construction of 3-D collaborative environments. Such environments provide immersive, creative and constructive interactions for knowledge acquisition by learning communities in the cyberspace. A project named ARCA (Collaborative Virtual Reality Environment for Learning) was designed and two prototypes were built aiming during its development of a teaching-learning environment based on Internet that can be a tool to support a differentiated pedagogical practice. We tried to provide conditions for a meaningful learning, using the attributes defined by Jonassen (Jonassen 1999) as illustrated in figure 1.

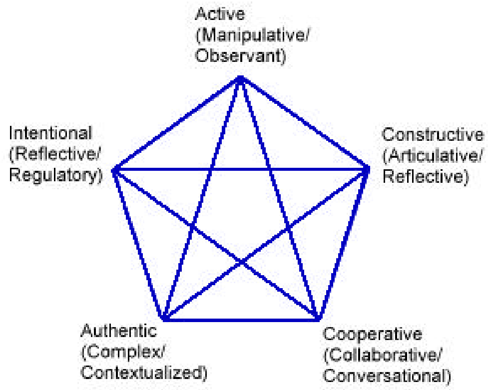

Figure 1. Attributed of Meaningful Learning

So a combination of technology elements was used to foster engaging students in meaningful learning through an environment that enables collaboration in a virtual reality environment. Aiming design, build and test such kind of environment it was choose use of a combination of tools derived from three computer science areas:

- **Virtual Reality** to build a virtual laboratory where learners may conduct experiments handling virtual devices able to show up significant proprieties of equipment and/or processes being targeted by the learning process, including augmented reality.
- **Collaboration** to promote conditions for supporting Vygotsky's theory of social cognitive development stating that "social interaction plays a fundamental role in the development of cognition" (Vygotsky, 1994).
- **Artificial intelligence** to make possible construction of pedagogical agents that supports learning in the virtual world.

With the results we get, students and teachers experienced telepresence, through an avatar. This way they can act and collaborate, not as themselves, but as a character, the avatar. The group analyzed several aspects for the creation and operation of this environment aiming to optimize it, both in terms of network performance and computation systems involved, and interface and conditions to support knowledge building.

2. ARCA VIRTUAL REALITY ENVIRONMENT

Aiming at finding a platform to support the virtual reality environment, the group considered some solutions such as *Cybernet Worlds*, *Galaxy Worlds* and *Other Worlds*. Although the results of each one were relatively similar, we chose the virtual active worlds manager system by Activeworld named The Active Worlds Educational Universe – AWEDU (Active Worlds 2001). It enables the adaptation and extension of initial functionalities in the fulfillment of environment requirements. Other significant aspects are its free availability for education use, and the use of a technological base quite advanced in terms of multi-user system in a 3-D environment accessed through the web.

AWEDU interface is framed in five intuitive and easy-to-use areas. The program offers a series of commands that are activated through a textual menu or buttons. In the central part the 3-D display and navigation area are located as well as fields for conversion via chat. At right side of the window a navigator is activated allowing interactions with web based applications.

2.1 ARCA Environment Components

Our premise was the construction of a computational environment able to be used in Internet connected networks. The model proposed, using AWEDU environment, may be presented through four entities used to represent the computational models and their respective relations (Figure 2).

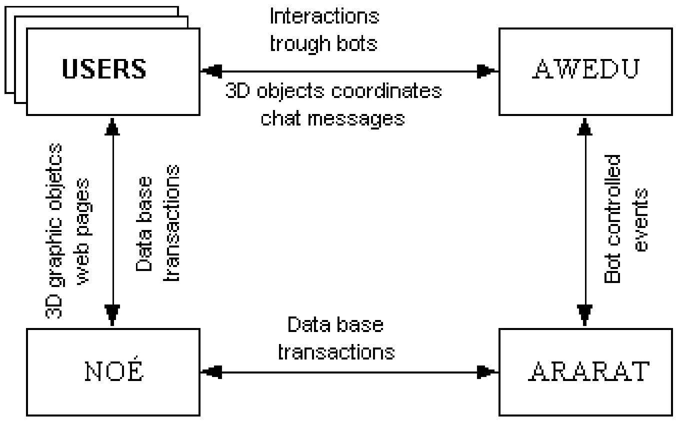

Figure 2. Diagram of computational components relations

- USERS: Comprise learners, teachers, specialists and support personnel related to a certain learning event modeled at ARCA. Relations between users and components AWEDU and NOÉ are set by an interaction between 2-D and 3-D objects. A browser of virtual worlds and the web controls and make them available.
- AWEDU: This component is in the network environment of Activeworlds. Its function is to keep track with configuration parameters such as, for example, registered users, objets and web pages storage place, chat manager and geographical coordinates of 3D objects. After running the navigation program a connection between USERS and AWEDU components is established. This way, it is possible to identify the user, and start displaying of virtual reality contents.
- NOÉ: The database of ARCA environment is implemented in this component. Besides HTML and PHP files, the database has a set of tables managed by MySQL application and 3-D objects in RenderWare Scrip language. Users make the insertion and retrieve tables information through PHP applications or applications built as bots. Bots are automated processes when executed remain in an endless loop, acquiring the ability of monitoring and acting based on events set in any virtual world. This component is installed at a Linux server.
- ARARAT: This component runs applications able to monitor events in learning spaces modeled for ARCA. User's logins and other interventions, by chat or 3D objects manipulation, are controlled through bots programming. Building this kind of application requires the use of a functions library available by Activeworlds. Additionally, the functions library of MySQL made possible to assign bots the ability of maintenance in ARCA data tables.

  The entire complexity that involves ARCA distributed computational environment is hidden from user.

Besides the options the browser provides, it is possible to identify the register of a virtual world in the interface, used in ARCA implementation. At the central window we find 3-D objects, among them we identify the construction of learning spaces as circular buildings, interconnected by tunnels. Below the 3-D visualization area we find interface elements used during chat sessions. Figure 3 shows different interaction areas available: virtual reality environment, chat tool and navigator window.

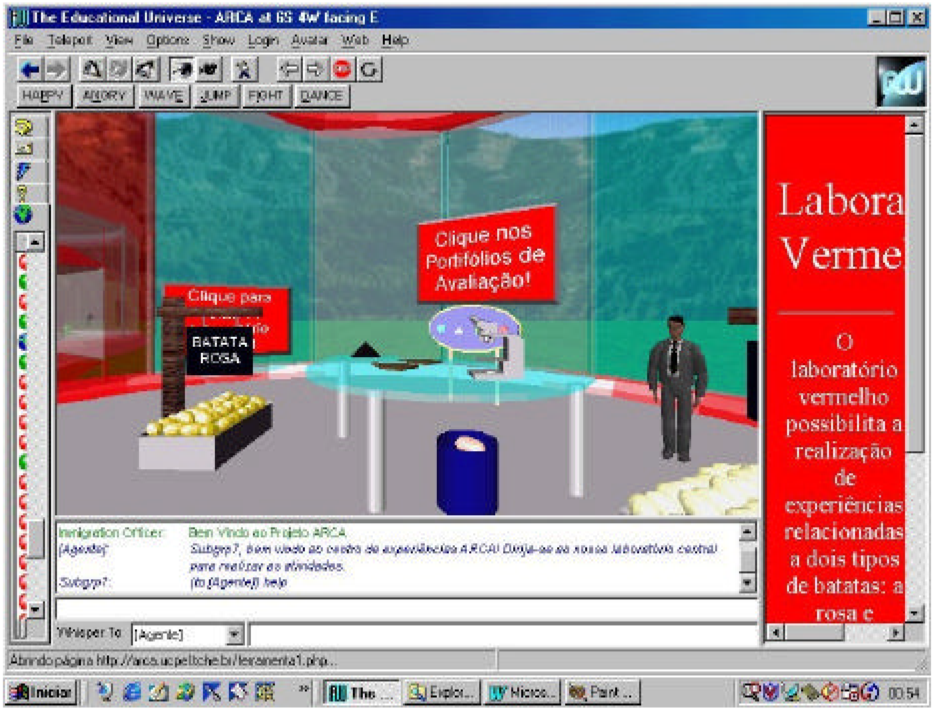

Figure 3. User's view

2.2 Vygotsky's Socio-Cultural Approach

To support the collective model of distance education, the purpose of this work has as theoretical foundation, the theory of Vygotsky (1998). One of the important concepts of the theory of Vygotsky is that mental activities are based on social relationships between the individual and the environment in a historical process and that this relationship is mediated by symbolic systems, through instruments and signs. For Vygotsky (1998) the signs are artificial incentives with the purpose of mnemonic aid; they work as middle ground for adaptation, driven by the individual's own control. The sign is guided internally. The function of an instrument is to serve as a driver of the human influence on the object of the activity; these are guided externally. Both have in common the mediation function.

Another fundamental concept in the Vygotsky´s theory is the proximal development zone (PDZ). In mentioning the PDZ, it is necessary to define which are the levels of the student's development: the Real Development Level (RDL) refers to the functions that the student already possesses. The Potential Development Level (PDL) determines the functions that a pupil can develop, through an adult's aid or from the collaboration of more experienced friends. PDZ is the distance between the real development level and the potential one. Besides these concepts, Vygotsky defends that cognitive functions happen first at social level for later to happen at an individual level: firstly among people (inter-psychological) and, later, within the person (intra-psychological). The psychological abilities, in the same way, happen initially in social relationships (inter-mental) and afterwards within the child (intra-mental).

3. COLLABORATIVE LEARNING

Most of pedagogical methodologies and, above all, methods involving new technologies prefer situations or contexts of individual learning. In counterpoint to this trend, the number of research involving promotion of learning using advantages of social relations, and collaborative learning has been growing over the last years. (Kumar 2001), (Larsen 2001).

Vygotsky's Theory of Social Cognitive Development (Vygotsky 1994) reasons that social interaction plays a fundamental role in the development of cognition. Instruction can be made more efficient when learners engage in activities within a supportive environment and receive guidance mediated by appropriate tools. Another notable aspect of Vygotsky's theory is that it claims "that instruction is most efficient when students engage in activities within a supportive learning environment and when they receive appropriate guidance that is mediated by tools". These instructional tools can be defined as cognitive strategies, a mentor, peers, computers, printed materials, or any instrument that organizes and provides information for the learner.

Collaboration is a process of shared creation: two or more individuals with complementary abilities interact in order to create a shared knowledge that none of them had before nor could get at their own effort. Collaboration also creates a shared meaning about a process, a product, and it was this way ARCA has developed its environment. The argumentation should be based on their existing knowledge as they try to accommodate new knowledge that is internally inconsistent. When the focus is on the learner's accommodation of conflicting ideas, it is necessary that the instructor act as a catalyst providing learning opportunities that enhance this process. Provision for opportunity to reflect on both the learning content and process is important. (Kanuka 1999).

Based on the premise that knowledge construction is a socio-linguistic process dependent upon the content and culture where it occurs, this view argues that we use conversational language to negotiate meanings that results in shared knowledge and understandings. By continually negotiating the meaning of observations, data, hypotheses and so forth, groups of individuals construct systems that are largely consistent with one another. Users experiment telepresence in the virtual laboratory as avatars, like shown in figure 3. Each user is represented by an avatar that may move in the scenario, touch objects and activate related behaviors. Results from an action commanded by one user is visible to any user in that room despite different views being presented depending of the position of each observer.

Coordination between user collaborating in this environment is done using a chat tool. While working in this environment, an user may interact using a chat tool that allows whispering (send a text message) to an specific participant or send a text message to all. A virtual tutor is a permanent participant (represented also by an avatar) and provide instructions about experiments available on each laboratory as well as other information related to that context. The virtual tutor behavior may be adapted to each virtual laboratory and experiment. In fact the virtual tutor is one of the pedagogical agent s used in this learning scenario as it will be described above.

3.1 Pedagogical Agents

Virtual environments offer rich opportunities to research and implementation of the so called ***Animated Pedagogical Agents***, which are autonomous agents that support human learning through interaction with students within the context of an interactive learning environment. Investigation points arise when pedagogical agents appear to the student as animated figures, undertaking a character, an avatar for example. In these cases, the agent, named animated pedagogical agent can be in a permanent dialogue with the student and produce a behavior that seem natural and appropriate (Elliot 1999).

Two differentiated techniques were designed to implement pedagogical agents. The first uses an agent based on artificial neural networks, genetic algorithmic and Jean Piaget's schemes theories in order to act with sensorimotor actions (type 1) (Ferreira 2001); the second is based on the BDI logic formal system (mental states of beliefs, desires and intentions) to act with more complex reasoning (type 2) as reasoning about some affective factors involved (Bercht 2000). These two agents develop differentiated and specialized functions that complement each other. Agent type 1 acts in the perception of the student's motor actions sending it to agent type 2 analysis. The final action is then the result of agent type 1 perception together with information coming from the environment and deliberation of type 2 agent about which pedagogical action should be performed.

On the other hand, in the case of the second technique, we have developed an investigation on the fact that many times a behavior is adequate, independent whether the belief is true or not. The fact that rational systems may exist does not mean that substituting a false belief for a new one always lead to a transformation of behavior. We may say then that there is a connection between the representations that motivate the production of a non-intentional effect and the representation of these effects on agents, which try to maintain beliefs and desires representations that determine the effect produced.

Investigations we are undertaking relate agents' situation and performance and try to provide subsides for better understanding of the motor phases and corresponding cognitive processes (agent 1), as well as the study of beliefs, desires and intentions according to expected behaviors (agent 2).

The implementation of pedagogical agents with differentiated architectures in ARCA environment enabled different tests, and also made possible the analysis of generation and behavior of agents through the integration of cognitive sciences, in the aspects of visual and tactile perception, motor coordination and the semiotic process of communication.

Techniques of Artificial Life were used to simulate some processes involved in the conservation and deterioration of aliments. Artificial Life is an area of Artificial Intelligence that wants to understand life. It tries to understand the main biologic dynamic processes and reproduce them in other artificial means, such as computational systems. Artificial Life sub-group studies how AL technology could be used to make it easier the process of learning in a virtual environment. That is, the student will be able to visualize and mainly to control the process of deterioration by microorganisms in a potato. A specialist of Food Technology Institute provided specific data about the evolutionary and deterioration process of aliments. Arts Institute created 2-D and 3-D multimedia images of potatoes for the Virtual Reality environment. Through the integration of studies carried out by the interdisciplinary team we have developed models that are able to make the sensorial appropriation of concepts established by laws of evolutionary processes, and of Artificial Life for learning promotion.

The first stage of this research was the theoretical study about the membrane of a living being. The objective was to study and simulate how the membrane exchanges information with the world. The study on the membrane provided the group a better understanding of life process. All living beings are autonomous systems. The objective of this work wasn't to propose a formal closed model; on the contrary, the objective was to make possible the emergence of an organized open system, an artificial organism that can model itself, a virtual membrane. In order to represent the self-organized system proposed, we decided to face some issues about the evolution process that do not allow its development. Firstly we analyzed the contradiction principle. Later we approached the principle of the third excluded, the Modal Logic (Ueno 2000). Based on comments of Poincaré (Poincaré 1964), Brouwe (Brouwe 1964) and Frege (Frege 1964) we present a proposal for the emergence of Artificial Life where an event is defined by some conditions, in this case the event is the rise of an organic structure that may form one life. However, an event may be observed or not, depending on the meaning of the concept for the observer. That is, the observer's viewpoint. This way, the observer's knowledge (subjectivity) becomes a need when one wants to observe a dynamic environment where virtual life evolves.

The second stage of this research has developed based on studies of the first. Its objective was to get information about the situation of virtual microorganisms, that is, information that would be obtained through the analysis of experiences with real microorganisms, according to information the specialist on food engineering provided. This phase had two different parts: the first resulted on an expert system responsible for receiving and storing information about the microorganisms behavior; the second part was responsible for receiving information of the virtual environment where the virtual microorganisms were, and correspond with the set of behaviors that describe the microorganism situation, based on the knowledge base updated by the specialist. The Expert System we built is different from the traditional ones, since its knowledge base is composed of mathematical formulae that generate microorganisms' behavior rules when operated. Data for the activation of these formulae are obtained from the environment (for example: temperature, potato quality, season, if the potato had been cut, if it underwent some kind of process, etc.)

3.2 Perception and Interactions

The initial proposal was to study the perceptive activity in the ARCA relating it to knowledge building. As a principle, it is clear for designers that interaction by itself is not enough to promote significant learning and knowledge building. The interaction must be at the level of meaning, whereby the learner seeks answers to new questions, arranges the material into new structures, or performs other manipulations which succeed in raising the level of comprehension. The perceptive effect we wanted for the environment was **immersion sensation**, once it could enable permanence, and motivate exploration, thus implying the possibility of knowledge building. Aiming at studying factors that incremented the immersion sensation we needed to redefine the notion of perception. Perceiving is producing sensor-motor correlation congruent with media disturbances in the process of operation of an organism in a certain coupling domain. This way it was possible to assert that virtual environments may produce perceptive domains different from those related to the sensorimotor experience acquired in non-virtual environments. This notion enabled the group to undertake some steps in the directions of provide user with the possibility of reverting phenomena that would be irreversible in traditional labs. Another result was that interactions between participants of the virtual environment would bring colaboration becoming an important factor promoting immersion sensation. A virtual tutor was included as a permanent participant, designed to give answers and advising to users. Interactions with virtual tutor are handled like interactions between user. A user may whisper to another selecting the target of the message typed in a chat area. Virtual tutor as a permanent participant is always available to receive messages and using chat robot technology. It was initially designed to give only a few pre-specified answers but latter its design was oriented to use natural language artificial intelligence chat robot technology to provide possibility of interactions with a more ergonomic human-computer interface.

3.3 Software Specification and Development

The virtual reality learning environment development used C Programming Language, JavaScript and PHP, as well as the manager system of MySQL database. The work platform being defined, we elaborated a methodology of development for the environment, strongly directed to the programming proceedings and graphic modeling. During research, many objects were aggregated or re-built, besides programming of control functions, that do not take part in AWEDU technology.

The start point of the specification and implementation process was a Storyboard created by a specialist on each content unit. *Storyboard* contained objects for the intended virtual set and a brief description of relations between these objects and their behaviors (how one may interfere on their state, appearance, etc.). Storyboards where discussed, refined and entity-relationship diagrams were derived. Yet based on Storyboard descriptive tables with the actions and respective transformations of learning events required by ARCA were elaborated.

In order to fulfill graphic requisites of ARCA we developed some basic constructive modules, exploring functions proposed by RenderWare language (RenderWre 2001). These virtual buildings were made in RenderWare Script (.rwx) and will used in AWEDU software. RenderWare Script language made possible to describe primitive 3-D objects. These objects joined through basic operations of rotation and translation resulted in buildings, which were named virtual labs for collaborative learning. On the other hand, objects of great constructive complexity (microscope, aliments, instruments, furniture, etc) were modeled in the graphic software Caligari trueSpace 4.3.

The development of software to amplify functionalities of AWEDU technology was carried out with the implementation of Bots, cgis and/or filling the Action box of Object Properties window. All these components could demand information insertion or retrieval from a MySQL database. Bots are a denomination of a category of programs that run in the virtual environment built with AWEDU technology. Such programs may perform functions the user can view, assuming the figure of an avatar or object. On the other hand, bots can be useful in the implementation of a number of routines hidden from the user's view. A library of functions is available in a Windows DLL file, making it easier the development of client/server applications in C language. Using EduVerse browser area to run a navigator, links can be activated through objects, enabling the information processing with CGI applications written in PHP.

4. CONCLUSIONS

First phase of the project aimed the design and development of a virtual laboratory focused on food production and conservation and more specifically on the potato handling process. Solution implemented included design of tools and procedures to apply on the potato being able to impact retention or lose of some characteristics on time. Time could be adjusted on demand by user to accelerate a process and made results visible more soon or to delay a process to follow step by step transformations occurring. Learner was able to freeze, cook, cut potatoes and inspect its proprieties after some time. Inspection could be done observing visual characteristic of the potato like change in color as well as the object of analysis could be brought to a electronic microscope that is able to "analyze" the potato giving values to level of certain components on its structure. Calculation of this values used artificial like algorithms.

Results we have reached until now make evident that 3-D virtual environments, may propitiate a more significant learning, making it easier the approach of complex topics and warranting the potential of social relations with the use of avatars and other graphic objects. However, in order to build learning environments of this nature, knowledge and an interdisciplinary praxis are necessary. In this first phase researchers from several area gave contributions: Computer Science, Cognitive Science, Arts, Food technology.

A second phase of the project aimed to not only repeat the process on a different focus area where there were more content specialist available and processes to be simulated were more simple. It was choose Physics Newton Laws. This phase included a more complex virtual tutor that could answer questions proposed in natural language. The knowledge base used by the virtual tutor was built using chat robot technology. Results were tested with learners from a secondary technical school. Motivation for learning more and beyond proposed time was some of the results.

A third phase will be developed including audio and video capability to allow voice communication between participants of the laboratory, natural voice understanding and voice syntheses on the interaction between participants and virtual tutor, as well as other content area.

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REFERENCES

Active Worlds Educational Universe. [Online]. Available: http://www.activeworlds.com/edu/awedu.asp [10 Dec 2002].

Bercht, M., 2000, Pedagogical Agents with Affective and Cognitive Dimensions. *V Congreso Iberamericano de Informatica Educativa*. [CD-ROM]. Viña del Mar, Chile.

Brouwe, L., 1964, Consciousness, Philosophy, and Mathematics. In Benacerraf, P. and Putnam, H. (Eds.) *Philosophy of Mathematics.* Prentice Hall.

Elliot, C. et al, 1999, Lifelike Pedagogical Agents and Affective Computing: An Exploratory Synthesis. In Wooldridge, M. et al (Eds.) *Artificial Intelligence Today, Lecture Notes in Computer Science 1600.* Springer-Verlag, pp. 195-212.

Ferreira, L., 2001. *Fazer e Compreender na Realidade Virtual: em busca da alternativas para o sujeito da aprendizagem*. PPGIE, UFRGS, Porto Alegre, Brasil.

Frege, G., 1964, The Concept of Number. In Benacerraf, P. et al., H. (Eds.) *Philosophy of Mathmatics.* Prentice Hall.

Jonassen, D. et al, 1999. *Learning with technology. A constructivist perspective*. Prentice Hall, Columbus, Ohio.

Kanuka, H. & Anderson, T., 1999. Using Constructivism in Technology-Mediated Learning: Constructing Order out of the Chaos in the Literature. In *Radical Pedagogy*, Vol. 1, No. 2 [Online]. Available: http://radicalpedagogy.icaap.org/content/vol1.1999/issue2/02kanuka1_2.html [10 Apr. 2002]

Kumar, V, 2001. *Computer-Supported Collaborative Learning: issues for research*. [Online]. Available: http://www.cs.usask.ca/grads/vsk719/academic/890/ project2/project2.html [21 Sep 2001].

Larsen, T, 1998. *Information Technology at the turn of the Millennium: Past, Present, and Future Trends.* IFIP WG 8.2 & 8.6 [Online] Available: http://www.bi.no/dep2/infomgt/wg82-86/proceedings/larsen.pdf [10 Dec 2002].

Mayer, R., 1996. Learners as Information Processors: Legacies and Limitations of Educational Psychology's Second Metaphor. In *Educational Psychologist*, Vol. 31 (3/4), pp. 151-161.

Pantelidas, V., 1995. Reasons to use virtual reality in education. In *VR in the Schools*, Vol. 1 No. 1 [Online]. Available: http://eastnet.educ.ecu.edu/vr/vr1n1a.txt [05 May 2001].

Poincaré, H., 1964. On the nature of mathematical reasoning. In Benacerraf, P. and Putnam, H. (Eds.*) Philosophy of Mathematics*. Prentice Hall.

RenderWare Object Creation, 2001. [Online]. Available: http://www.tnlc.com/rw [27 Sep 2001].

Resnick, L. et al. (Eds.), 1991. *Perspectives on Socially Shared Cognition*. Washington D. C.: American Psychological Association.

Ueno, Y., 2000, Arising Artificial Life. *Fourth German Workshop on Artificial Life (GWAL2000)*. University of Bayreuth, Wissenschaftszentrum Thurnau.

Vygotsky, L. S. 1994. A formação da mente. Martins Fontes. São Paulo - Brasil