Distance Education Using a Desktop Virtual Reality (VR) System

M. Travassos Valdez
Departamento de Electrotecnia
Instituto Superior de Engenharia de Coimbra (ISEC)
Coimbra, Portugal
valdez@isec.pt

C. Machado Ferreira
Departamento de Electrotecnia
Instituto Superior de Engenharia de Coimbra (ISEC)
Coimbra, Portugal
cmacfer@isec.pt

F. P. Maciel Barbosa
Faculdade de Engenharia
Universidade do Porto
& INESC TEC
Porto, Portugal
fmb@fe.up.pt

***Abstract*—The constant changes occurring in today's teaching and learning processes provide a continuous improvement in the interaction of information. At the same time, globalization and the need for streamlining time facilitate the development of new methods of imparting knowledge.**

With the new information technologies, new forms of learning occur adding greater dynamism to the information. This form of learning, which optimizes time and space, is known as distance learning and it is being amply used in many different areas. Distance education presents the advantage of facilitating the teaching and learning processes without face-to-face interaction as knowledge is transmitted, partly or as a whole using technology.

In fact, technological innovation has assumed a vital role in education. Looking to achieve more efficiency in carrying out the various activities, the job market constantly requires an investment in new skills and knowledge so that the professionals can operate the equipment and working tools, successfully and with quality.

This paper presents a new system of learning a curricular unit of Circuit Theory using desktop virtual reality (VR). The software provides the possibility to understand the relationship between the physical concepts of an electrical circuit, direct or alternating current, through computer simulations and animations.

This work was developed to demonstrate how a desktop VR prototype, "Virtual Electric Manual"-VEMA, can be applied to an engineering unit and used to enhance security and resourcefulness in using electrical equipment. Several interactive scenes were developed to illustrate the idea using a measurements and instrumentation laboratory as virtual environment.

A range of interactive learning environments are presented: the menu with the first interactive experiment is the simulator of a DC circuit. It allows the student to analyze the setting up of a parallel, or series-parallel resistive circuit series powered by direct current; the second menu, features the simulator of an alternating current circuit and demonstrates how the student can perform the analysis of a circuit with resistors, inductors and capacitors; the third interactive experiment is the simulator of a three-phase alternating current circuit; the fourth menu refers to a study on the transitional phenomena. Finally, the fifth menu is an interactive experiment related to the phenomena of resonance.

VEMA offers students the opportunity to understand the processes, helping them to better discern the procedures and trains them to interact with the equipment.

The VEMA prototype addresses these issues and highlights the potential benefits of using VR for this purpose. Each experiment will provide technical and scientific knowledge in order to give the student/user adequate information and training in the subject.

Keywords— circuit theory; electrical circuits; interactive circuit; learning object

I. Introduction - The Teaching-Learning Process

To promote teaching and learning is no simple task as it requires great accuracy and a number of procedures to be taken into account in order to stimulate acquisition.

Teaching is the planned response to the demands of the natural learning process in order to obtain optimal results; the teaching process must respect, facilitate and enhance the natural learning process [1].

Learning requires continuity and a logical sequence as it is more than simple transmission of information; it requires methods, techniques, procedures and instruments to obtain satisfactory results. Each student is responsible for his/her own learning, and the teacher is just a facilitator and advisor. It is important to respect the students' different characteristics and their learning process should be accomplished in a more individualized manner.

Three approaches to education can be referred: full-time education, part-time education (part at school, part virtual or at a distance) and distance education (virtual). Face-to-face or full-time education is the conventional type of education and the most widely used approach in normal courses at any level, requiring teachers and students to be together in the classroom. The second approach combines learning in the classroom and at a distance using modern technology. Distance education may or may not need to have face-to-face moments as teachers and students are physically separated in space or in time, while being able to interact through communication technologies, i.e. virtually [2].

Technology has brought numerous benefits, extending the scope of the teaching and learning processes, arising as a facilitator and a strategic tool to promote improvement in the methods and practices, optimizing education in general, affording new and innovative opportunities in the way education and teaching are designed.

Thus, it is necessary to find new strategies to teach engineering, where the teacher is no longer the only source of knowledge and information, but creates the opportunities so that students become more actively engaged in the learning process, learning how to find and filter the information, as well as build their own knowledge. It is to that extent that technologies must be understood and used as tools in the pursuit of this new paradigm.

II. DISTANCE EDUCATION

Higher education has evolved in the last decade with the use of information technology. This change was called distance education, a teaching method in which the student does not need to meet with the teacher on a certain day and time. The student may be either at home or at work and may have no interaction with the other parts, either the teacher or other students. It has allowed the institutions to resolve geographical gaps in order to reach the largest number of students. On the other hand, it paved the way for the "non-traditional" universities oriented for "adult work", in a narrow range of graduation programs, compatible with the current demands from industry [3].

It is also important to mention that distance education is becoming increasingly appropriate for non-academic studies, such as corporate training environments [3].

It should be able to meet the operational requirements through a synthesis of components, attributes and relationships. Distance education technologies should promote educational and academic goals respecting the organizational needs of each institution, namely collaborative education. The technologies with the capacity to introduce more realistic professional skills also have the potential to introduce new concepts in education and in the classroom.

The use of technological resources in teaching requires an evaluation of the whole teaching and learning processes. It will also be necessary to reflect upon the choice of methodology and tools that better promote the new proposal. Distance education is a form of planned learning requiring special organization, attention and techniques, as well as specific electronic communication methods and other technologies.

The most motivating feature was the quick and easy way of furthering student/teacher interaction. This interaction can be carried out using various methods and techniques with synchronous and asynchronous approaches.

The direct transfer of face-to-face teaching contents to a distance learning format does not ensure the adequate solution to create the syllabuses of distance learning courses. The learning process has to be more than just receiving information and acquiring knowledge. The choice and design of the contents must be based on specific pedagogical guidelines and assumptions inherent to the particular characteristics of the intended approach [4].

The latest generation of distance education is characterized by virtual communities with easy-to-use, interactive and accessible e-learning systems.

A virtual distance learning system must incorporate features such as: good accessibility; total control of the educational material; high level of interactivity; a dynamic environment with access to instructional resources; flexibility, allowing the improvisation of teaching materials; self-learning, supplying students with all course materials and promoting their capacity for independent study.

This system must provide other skills such as: asynchronous interaction mode; access to teaching materials independently of location and time, providing great flexibility; time for reflection and observation, in which students have the opportunity to think about the ideas and consult other sources; learning from home or work; text-based asynchronous systems that require narrow bandwidth and less sophisticated computers, facilitating global access and reducing costs [5-7].

As it was previously referred, any type of distance education requires an adequate attitude and choice of pedagogical methods, and additional resources tailored to the profile of the students of each course. In addition, as there is less social interaction between teacher and students, greater importance must be given to the educational materials used to motivate the students that are scattered in place and time.

The use of information technology as a support to education is very wide. There is a variety of software developed for educational purposes, the educational software (ES), which is taking an increasingly important role in education. For some authors, all software can be considered ES, provided that it uses a methodology that contextualizes the teaching and learning processes [8]. Quality is the main aspect to be taken into account with this software as the market has been providing more and more products with numerous applications and a wide range of resources.

III. THE LEARNING OBJECT

According to Paula Escudeiro, a Learning Object (LO) is a digital interactive feature structured and normalized with a specific educational goal, contents and learning activities and evaluation system [9]. E-contents are any web format contents available on the internet.

The LOs are subsets of e-contents, with interactive contents, structured and standardized according to a format specification and reference model [9].

Currently there are several specification standards for the design of an LO. Paula Escudeiro suggests a normalization of LOs using the SCORM reference model–(Sharable Content Object Reference Model). This model supports the development of learning contents in order to ensure reuse, interoperability, durability and good accessibility.

According to Silva and Fernandez, the construction of a learning object should have three characteristics: to stimulate the reasoning and critical thinking (minds-on); to address issues relevant to students (reality-on) and offer the opportunity for research (hands-on). They state that the simple transfer of contents from paper to an electronic support does not bring any advantage from a didactic-pedagogic point of view. The task of evaluation is thorough because it requires a theoretical basis for the analysis of the concept to be studied and explored by the technological resource as well as for the design project. Silva and Fernandez refer that some LOs only have graphic and interactive functions [9].

LOs simulations and animations should provide practice similar to the one acquired in real life and thus become a viable resource in situations where it is not possible to carry out practical sessions. Therefore, it is considered that the LOs can assist the lectures in the acquisition of concepts as well as provide support for the theoretical-practical and laboratory lessons integrating the instruments that allow cognitive learning based primarily on student interaction with the desired environment.

Computer simulation is an efficient technique to be used in practical work as it minimizes the teachers' concerns regarding time, costs or risks that involve the choice of inappropriate, ineffective or potentially dangerous experimental strategies.

The possibility of testing different ways of monitoring the evolution of cause-and-effect relationships, visualizing concepts from different points of view and confirming hypotheses transforms animations and simulations in powerful tools to promote new ideas and arouse curiosity, relate concepts and solve problems. These interactive activities provide the opportunity of exploring scientific phenomena and concepts, often impractical or nonexistent in schools due to budget and security issues. It also allows experiments to be performed even when a class is not being held.

This paper addresses Circuit Theory systems, more specifically laboratory practices geared towards teaching and learning. The choice was made from observing the needs in the specific context of a measures and instrumentation laboratory, mainly related with access to the means and equipment to carry out laboratory practice. The purpose of the work is the use of virtual experimentation to carry out laboratory practice and also as an alternative tool to meet the needs of access to the means and equipment of the laboratory.

It is in this perspective that this work was conceived, having as goal the development of a LO, assuming that it may be a possible alternative to represent models of interactions that occur within the object of study. It may help improve the understanding of physical concepts, in particular those involved in the subject of electrical circuits. It aims at characterizing the learning process through a series of situations that can be repeated, leading to a change of attitude and involvement of students. It is assumed that the use of this tool can lead to the acquisition of a specific set of skills, a better and meaningful practice and significant learning.

IV. Objectives of the Educational Software (ES)

According to Circuit Theory I course contents there is a set of laboratory experiments that provide students with adequate training and knowledge of circuit theory. The goal is to provide the technical knowledge to analyze alternating and direct current electrical circuits, in particular, to know and understand the various parameters of an electrical circuit: current, voltage, power, power factor, etc.

When one ES is created, it is also very important to characterize the type of student to whom it is addressed [10].

The ES will be the best alternative to supply the necessary learning and practice for the students who are unable to attend laboratory lessons due to various personal, professional or logistics constraints. The ES can serve as the basis for experiments and to deepen learning, even for those students who are able to attend laboratory classes.

There should be two types of documents in the development of educational software: one of design and the other to be used as study support [9]. The support document should clearly state the objective and relevance of the project in higher education. In order to be understood by all those involved, it will be necessary to describe, in plain language, the requirements the ES intends to develop as well as the technical issues. The models to be used may include case diagrams and others of more general description to give a general overview, mentioning who is involved in the program and which are the use cases.

The type of ES users must be identified beforehand in order to create a use case; they are the called actors. The use cases are used to model a SE and they must be chosen to attain specific goals. To build any scenario it is necessary to identify the functional requirements of the system, specifying the context of the ES, and describe clearly how it will interact with the student/user.

Each experiment must provide technical/scientific knowledge to be able to offer instruction and experimentation of that particular topic. Virtual trials do not have to be sequential although the sequence of work can help to construct cognitive models necessary to the learn about the entire model.

At the end of each virtual simulation it is expected that the student will feel at ease to enter a real laboratory and perform the same type of work, without feeling any negative impact or maladjustment.

In short, with this SE:

1. The target user may be a student of any age with some basic knowledge of Circuit Theory.
2. It can be used both by the teacher and the students. In the case of the teacher, it may be used to illustrate experiments performed outside the lab.
3. It is possible to be used in any computing environment suitable for this type of software.

4. Each computer can be shared by no more than two students in the classroom.

By using constructivist theories, a particular scenario was designed to further the interaction process, thus triggering the whole procedure as an internal learning process. It is in this particular scenario that the actions carried out by all actors, teachers and students, converge in learning processes [11-13]. However, there are relevant aspects that need to be taken into consideration. It necessary to provide a basis of knowledge and information to assist the student in the activities he/she will undertake. As the constructivist theory suggests, it is the student who will have to take control of his/her own learning process.

For this scenario, it was necessary to create some type of support symbols such as objects, texts, graphics editing, etc. Simulation was used so that the information is presented in a visual/graphic and intuitive format, allowing the student to observe relevant phenomena and manipulate variables/parameters. Other elements may also improve the proposed scenario, as long as they are considered required and important.

The ES is created to be available on the internet and its use may become universal. This tool will provide support to study and learning for any student unable to attend the laboratory sessions. It will provide the necessary conditions to be successful in performing a real task or during a formal laboratory examination at school. In addition, any student who can attend all the laboratory lessons will find a complementary practice tool in this educational software.

This Learning Object (LO) prototype presents interaction models related with the subject of study, helping to improve the understanding of physical concepts, in particular those involved in the subject of electrical circuits. The learning object used in this work consists of the models of equipment and its use in educational laboratory software available for students. Most of the laboratory objects were modeled using the Autodesk ® 3DS Max ® software. 3D Max, VizUp 5.0 WireFusion ® and HTML5 was the software used to achieve the intended objective.

V. Description of the Model of Educational Software

The overall idea was to create a three-dimensional model (3DS Max, Maya, Cinema 4 D, SketchUp, Blender, LightWave or any other 3D tool), reduce the size of the 3D objects with VizUp and then export them to WireFusion, where it was possible to add some interactivity. However, all animations had to be previously built in the source program of the 3D model. The last step was the production of interactive contents using HTML5, CSS3 and Javascript and the introduction of the presentations on the web as offline presentations.

In the present case, the basis of the project was the construction of a 3D lab environment (Measures and Instrumentation) where the equipment and the components can be seen and manipulated. The project involves simple electrical schematics, which later can be changed in values, presenting new results, and displays a set of menus and submenus to support experiments.

This work was developed to demonstrate how a desktop VR prototype, “Virtual Electric Manual” - VEMA, can be applied to an engineering unit and used to enhance security and resourcefulness in using electrical equipment. Several interactive scenes were developed to illustrate the idea using a measurements and instrumentation laboratory as virtual environment.

The menu with the first interactive experience is the simulator of a DC circuit. It allows the student to analyze the setting up of a parallel, or series-parallel resistive circuit series powered by direct current. In this scene, and together with these simulations, there are texts supplying the theoretical explanation of the experiment performed.

The second interactive menu presents the simulator of an alternating current circuit and demonstrates how the student can perform the analysis of a circuit with resistors, inductors and capacitors in series, in parallel or in series-parallel AC powered; it also provides guidelines based on the texts, allowing the student to clarify the numerical expressions used for the resolution of the circuits.

The third interactive experiment, the simulator of a three-phase alternating current circuit, describes the potential of VR for electric three-phase circuit representation, with star or delta configurations, to enable greater understanding and rapid knowledge transfer. It also provides the opportunity for interactively designing a setting up and safely investigates the consequences for the user.

The fourth menu, with the fourth interactive experiment, refers to a study on the transitional phenomena.

Finally, the fifth interactive menu and experiment is connected with the series or parallel resonance phenomena.

The practical use of the prototype consists of experimental interactive scenes. A user interface allows the student to get in and out of each scene intuitively.

In addition to the experimental interactive scenes already mentioned, there are other menus: the main menu with a "Home" page; a menu on the various laboratory equipment. There are also the menus: "3D Lab", "About", "useful Links" and "Contacts" already implemented and tested (see Fig. 1).

Fig. 1. VEMA’s first page

The whole menu, with the various equipment, is presented in Fig. 2.

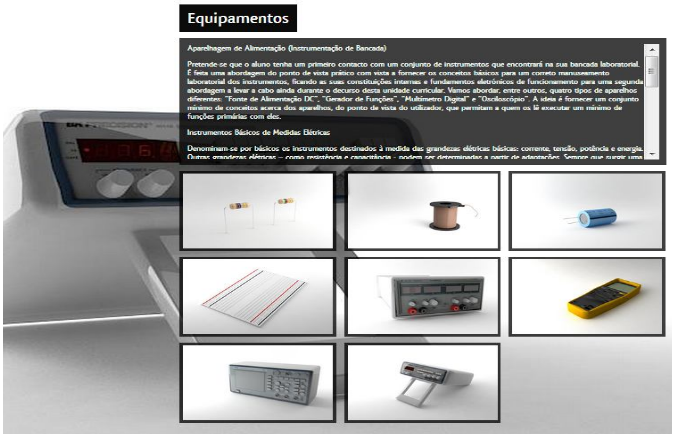

Fig. 2. Equipment menu in VEMA

When the students "enter" the virtual environment, a variety of settings and various equipment is made available, via the GUI (Graphical User Interface). The purpose of this information is to give them an overview of electrical circuits and the corresponding equipment and provide an adapted environment.

Inside the simulator, the students can visualize a virtual laboratory installation and interact or simulate a value in any of the interactive devices, such as a power supply, resistors, etc. When these parameters are changed, the circuit is automatically updated and the students can immediately see the impact of choices in real time.

The contact and experience with the virtual environment can allow students to quickly be absorbed into small electrical projects. They can easily identify the parameters involved and thus develop a greater familiarity, and hopefully learn to design an electrical circuit with greater confidence.

VI. Discussion

The theories of education and cognitive science support the role of VR as a training tool [14-18]. According to Chittaro, constructivism is the main pedagogical support that stimulates the educational use of VR [19]. Constructivists argue that individuals learn through their experience of the world through a process of construction of knowledge, which happens when students intellectually invest in meaningful tasks [20]. It can be concluded that the interaction with an environment or a process is fundamental to the learning process and VR offers one of the most appropriate methods to create a contextualized training activity.

The learning theory also suggests that VR can be a beneficial tool because it confirms that knowledge must be gained through contextualized activities in authentic situations, which reflect the way it will be used [21-24]. Finally, researchers point out that students acquire more information if more physical senses are involved in the learning process and, as such, VR can be a very useful tool.

The VR program developed in this work used a WireFusion 5.0 ® authoring tool that allowed its construction with low cost of implementation by using an educational license. This was a significant factor in the choice of this specific program for the development of VEMA. From the educational point of view, VEMA is not seen as a substitute of the traditional teaching methods, but only as an additional resource, which can significantly improve students' reasoning and motivation.

The use of the circuit simulator as an educational tool is a student-centered approach and moves away from the traditional learning techniques. Students can learn for themselves, investigating the results arising from data entered by them, in their own time.

Because VR desktop applications are reusable, and advantageous for updates, they will potentially allow a reduction in training budgets; furthermore, because it is possible to distribute them on the web, it presents itself as a really attractive option both for education and industry.

VEMA offers students an opportunity to deepen understanding, increases their insight into the procedures and trains them to interact with the equipment. This prototype addresses these issues and highlights the potential benefits of the use of VR for this purpose. Each experiment provides technical/scientific knowledge in order to give the student information and training in the relevant study contents.

VII. Conclusion

In the design of a virtual reality system, the selection of the most appropriate tool is an essential component in the development of a VR program. The level of flexibility and pre-programmed components can vary substantially among software tools. Many resources require a special attention from the designers regarding the supported file formats for 3D importing models, polygon count, object sizing, type of animation, collision detection, extensibility, support for VR input/output devices, 3D libraries, widgets, development support and methods of publication of an application.

The added value of these various features in the educational context is that they contribute to the construction of new virtual environments, able to benefit the communication between teachers and students and among themselves, thus creating new opportunities for each student to participate more actively in his/her own learning construction process. Rather than being seen as mere information files, these e-learning platforms should be perceived as a means to promote interaction and experimentation through technological resources [25].

The challenge for educators is to be able to act as facilitators of that process by guiding students to become critical and engaged citizens in this new information society. On the other hand, Institutions must develop programs that allow students and teachers to be part of this whole project. The economic, social and technological changes require individuals to learn to tackle the new challenges posed by these constant transformations.

It is important to raise students' awareness that learning is a continuous process; much more than a duty, it is a right. The advantages offered by the media and the possibility of processing information, through increasingly powerful computer programs, can bring significant benefits to the learning process.

References

[1] Sandra Carvalho dos Santos, O processo de ensino-aprendizagem e a relação professor-aluno: aplicação dos "sete princípios para a boa prática na educação de ensino superior". Caderno de Pesquisas em Administração, v.8, n.1, p. 69-82, 2001 (in Portuguese).

[2] J. M. Touriñán and A. Guimaraes, Educaçao eletrónica. Orientações estratégicas de valor educativo. Quinto Simposium Ibero-americano en Educación, Cibernética e Informática. SIECI 2008. Código de artículo X781AM. En edición en la Revista Contacto (Cabo Verde). 2008 (in Portuguese).

[3] A.P. Rovai, M.K. Ponton and J.D. Baker, Distance learning in higher education: A programmatic approach to planning, design, instruction, evaluation, and accreditation. New York, New York: Teachers College Press. ISBN: 9780807748787, 2008.

[4] J. R. Lima, Z. Capitão, E-Learning E E-Conteúdos Aplicações Das Teorias Tradicionais E Modernas De Ensino E Aprendizagem À Organização E Estruturação De E-Cursos - Centro Atlântico, 2003 (in Portuguese).

[5] A. Ruplis and E. Priednieks, Recent Development of Some Learning Tools for Course. Electrical Engineering and Electronics, ISSN 1392 - 1215, Nr. 7, Page(s): 71. 2006.

[6] M. G. da Silva and M. A Fernandez., Recursos informáticos projetados para o ensino de ciências: bases epistemológicas implicadas na construção e desenvolvimento de objetos de aprendizagem. In Objetos de Aprendizagem: uma proposta de recurso pedagógico. Brasília: MEC, SEED, 2007. pp. 27-37. ISBN: 978-85-296-0093-2. Available: http://www.RIVED.mec.gov.br/artigos/livro.pdf. visited in: 5 jul. 2012 (in Portuguese).

[7] Hsiu-Mei Huang, Ulrich Rauch, and Shu-Sheng Liaw,. Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach. Computers & Education, vol. 55, no. 3, Page(s): 1171-1182. 2010.

[8] Lúcia M. M. Giraffa, Uma arquitetura de tutor utilizando estados mentais, Tese de Doutorado. Porto Alegre: CPGCC/UFRGS, 1999 (in Portuguese).

[9] P. M. S. Oliveira Escudeiro, Prototipificação Evolutiva de Software Educativo Suportado por Bases de Dados Relacionais, Universidade Aberta, Ph. D. thesis, 2008 (in Portuguese).

[10] J. E. Hinostroza and H.Mellar, "Pedagogy embedded in educational software design: report of a case study", Computers & Education 37, 27–40, 2001.

[11] BinShyan Jong, YuLung Wu, TeYi Chan, Dynamic Grouping Strategies Based on a conceptual Graph for Cooperative Learning, IEEE Transactions on Knowledge and Data Engineering, vol. 18, no. 6, pp. 738-747, doi:10.1109/TKDE. 2006.93, junho 2006.

[12] G. Gabrysiak, H. Giese and A. Seibel, Towards Next Generation Design Thinking: Scenario Based Prototyping for Designing Complex Software Systems with Multiple Users, in H. Plattner, C. Meinel & L. Leifer, Design Thinking: Understand-Improve-Apply, Springer Verlag, 2010.

[13] D.W. Johnson and R.T. Johnson, Learning Together and Alone: Cooperative, Competitive, and Individualistic Learning, 5/E. N.J.: Allyn and Bacon, 1999.

[14] B. Z. Perez, M. M. Marin and E. I. Perez, Developing a Virtual Environment for Safety Training, in Electronics, Robotics and Automotive Mechanics Conference, Morelos, pp. 545 - 550, 2007.

[15] G. Funchal, M. Moy, F. Maraninchi, L. Maillet-Contoz, Faithfulness Considerations for Virtual Prototyping of Systems-on-Chip, Verimag Research Report no TR-2010-13, May 18, 2010.

[16] Yang Wang, Lifeng Wang, Zewei Zheng, Application of Virtual Prototype Technology to Simulation Test for Airborne Software System, Advances in Electronic Engineering, Communication and Management Vol.2, pp 653-658, 2012.

[17] Stephen C. W. Kong, A Framework for Implementing Virtual Prototyping in Construction, 2nd International Conference on Emerging Trends in Computer and Image Processing (ICETCIP'2012) June 30-July 1, Bali, 2012.

[18] A. Fratu, M. Fratu, Simulation of articulated robots for virtual prototyping in dynamic 3d environments, Bulletin of the Transilvania University of Brasov, Series I: Eng. Sciences, Vol.5(54), No. 1, 2012.

[19] L. Chittaro and R. Ranon, Web3D technologies in learning, education and training: Motivations, issues, opportunities, Computers & Education, vol. 49, no. 1, pp. 3-18, August 2007.

[20] Conceição-Runlee, S. and Daley, B.J., Constructivist learning theory to web-based course design, in Proceedings of the 17th annual midwest research-to-practice conference in adult, continuing and community education, 1998.

[21] T. Huang, C. W. Kong, H. L. Guo, A. Baldwin, Heng Li, A virtual prototyping system for simulating construction processes, Automation in Construction 16, 576–585, 2007.

[22] S.H. Choi and H.H. Cheung, A versatile virtual prototyping system for rapid product development, Computers in Industry, Volume 59, Issue 5, pp. 477–488, May 2008.

[23] S.H. Choi and H.H. Cheung, A multi-material virtual prototyping system, Computer-Aided Design 37 (1) 123–136, 2005.

[24] Rudolf Volner, Engineering Environment and Avionics Virtual Prototyping, Electronic technical journal, Number 2, Volume VII, ISSN 1801-674X, July 2012.

[25] E. Ai-Lim Lee, W. Wai and C. Fung, How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach, Computers and Education, vol. 55 (4). pp. 1424-1442, June 2010.