NETWORKED LEARNING PHYSICS OF SEMICONDUCTORS THROUGH A VIRTUAL LABORATORY ENVIRONMENT

K. Ninos, I. Stavrakas, G. Hloupis, C. Anastasiadis and D. Triantis

Department of Electronics, Technological Educational Institution of Athens, 12210, Greece

Abstract: Virtual laboratory tools have been introduced long ago. Such tools have been used by students to improve their performance and stimulate their interest. When the high cost of hardware replacement and maintenance is contrasted to the flexibility of adding new subjects in a laboratory course, the virtual laboratory tools render a power tool for educational purposes. Since students statistically do not spend adequate time preparing for laboratory modules, new methodologies and software have been sought to help students increase their laboratory skills and understanding. In this work a virtual laboratory environment dealing with Semiconductor Physics assignments is described, discussed and evaluated. Semiconductor Physics was chosen since it is a first year module not connected to any background knowledge familiar to the students. The evaluation was made by providing the software to some of the students and comparing their performance to that of students having no access to the software. It is concluded that the software tool provided to the students before taking the laboratory helped to increase their performance. It was also observed that this tool mainly serves weaker students since, according to the evaluation tests, they are mainly helped to achieve a pass score.

1 INTRODUCTION

The evolution on the network technologies and the computing systems has been applied to higher education Institutions in several fields (Ubell, 2000; Fox, 2002; Ali et al., 2004). The use of new technologies in software development has enabled the combined application of hardware and software in the teaching procedure of both theoretical and laboratory oriented courses (Hart 1993; Hudgins et al., 2002; Cheng et al., 2004; Dede, 2000; DeBord, 2004). There is an increasing interest world wide in offering more flexible education systems based on the use of Web resources and remote education. Specifically, virtual laboratory tools have been introduced a long time ago. Initially, they were used to increase the flexibility of controlling hardware and running experiments (i.e. Labview, Vee, Matlab, etc). Consequently, they were adopted in the learning procedure in order to increase the performance of the students since they constitute a user-friendly tool and stimulate them to use it in their study. Additionally, when the high cost of hardware replacement and maintenance are put in

contrast to the flexibility of adding new subjects in a laboratory course it can be concluded that the virtual laboratory environment tools render a power tool for educational purposes. Such activities and new tools have been proposed by several researchers (Tsiakas et al., 2007; Stavrakas et al., 2005; Cheng et al., 2004; Hart,1993; Hudgins et al., 2002). The implications of these tools on the performance of the students are still under investigation (DeBord et al., 2004; Epstein et al., 2001; Ali et al., 2004). The effectiveness of the virtual laboratories that are closed (i.e. taken simultaneously by all students) or open (i.e. taken at anyplace anytime) are also investigated as well as other methodologies of using network enable tools (Soh et al., 2005 and references therein; Kumar 2003).

The Technological Educational Institution of Athens in the Framework of Education and Initial Vocational Training Program titled: "Upgrading of Undergraduate Curricula of Technological Educational Institution (T.E.I.) of Athens" has developed several platforms that constitute novel tools in the educational processes (Tsiakas et al., 2005). Specifically, e-examination methodologies

have been adopted and evaluated regarding their impact on the students' performance. Additional tools, that enforce student – teacher interaction, have also been modified and adapted to the needs of each academic department (Tsiakas et al., 2005; Stergiopoulos et al., 2006; Triantis et al., 2004, Triantis et al., 2009; Ventouras et al., 2010).

Since statistics show that students do not spend adequate time for an upcoming laboratory module in order to become familiar with the terms and the underlying theory, new methodologies and software have recently been developed and are provided to the students in order to increase their performance in laboratory modules. In this work a virtual laboratory environment that was built is described and discussed. The students' performance is studied after applying the new methodology. Open and close laboratory methodologies have been tested. In the present paper the work is organized as follows: A short initial paragraph describes the motivation of this research, escorted by a detailed description of the designed and implemented software that were based on a case study. In the last section we utilized two evaluation tests to measure the impact of using the system on the students' learning outcome. Initially, the software was used as a method to prepare the laboratory module and in the second evaluation test the software was used as a tool to conduct the laboratory experiment.

2 DISCUSSING THE NEED

The motivation to measure the influence of virtual laboratory experiments on the learning outcome of students was an initial survey (through questions) about the time the students spent to prepare a laboratory module. A number of 133 students participated in this process during the 2007—2008 academic year. The statistical analysis of the answers is summarized in the pie diagram of Figure1. In general, statistics indicates that most students do not spend adequate time on studying a laboratory module. Figure 1 shows that 45% of the students actually do not spend any time before a laboratory module, in order to become familiar with the terms and the concept of the exercise. The above results dictate that only 25% have previously spent a sufficient amount of time in order to get prepared for the module.

This observation was a motivation in order to propose a new way of conducting laboratory experiments in order to attract the students' interest
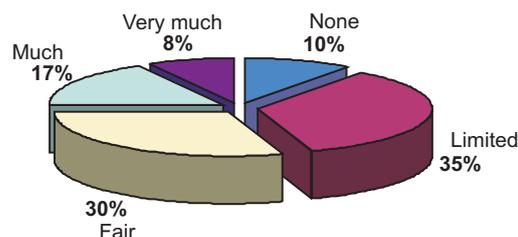

Figure 1: Time spent by students to prepare an upcoming laboratory module.

and increase their performance. Additionally, for evaluation purposes, the performance of the students was compared before and after the use of new tool for preparation and teaching the module.

3 DESCRIPTION OF THE SYSTEM

A virtual laboratory environment was built in order to teach physics of semiconductors. The system has been developed through a Java programming environment and consists of a server and a client application in order to become network enabled. Initially, the student designs the experimental circuit through a user-friendly interface. The next step is to connect the necessary instruments to perform measurements and to set all the experimental parameters. Evaluation of the built model comes next. The final step is the execution of the experiment. After the experimental procedure is completed the student may require data plotting and datasets exporting (which can be done in .xls format).

An important advantage of this software is the option provided to the student to approach the experiment either from a theoretical point of view (getting this way results as expected according to the theoretical formalisms) or to introduce to the circuit the device tolerance factors and transients (in order to have a more realistic experimental result that could be met in a laboratory environment).

Several experimental circuits and their corresponding analysis have been designed and added to this software. The most important ones deal with the I-V characteristics of non-linear electronic devices and the calculation of the energy gap of Ge crystals.
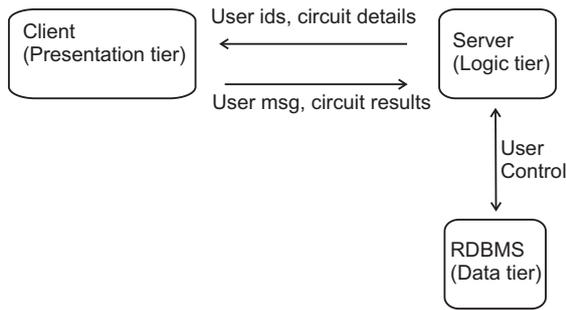
Figure 2: System architecture.

The basis of this modelling software is a three-tier client − server architecture. In this architecture, the user interface, the functional process logic, the data storage and access are developed and maintained as independent modules, on separate platforms. Figure 2 shows schematically the architecture of the system. The client sends the experimental description to the server and the server responds sending the results back. In addition, the server is connected to the database system (RDBMS) for checking the user accounts.

4 CALCULATING THE ENERGY GAP (E_G) OF GE CRYSTALS: A CASE STUDY

A case study is described here and particularly an experiment dealing with the calculation of the energy gap of Ge crystals. For the calculation of Eg the dependence of the sample resistance on temperature is monitored by recording the values of resistance versus increasing temperature. This is accomplished by using a Ge crystal sample placed on a heating resistor and by recording the sample resistance and temperature using an ohmmeter and a thermocouple respectively. A variable voltage source feeds the heater to increase the sample temperature.

Figure 3 depicts a typical Eg measuring circuit. The program validates the completed circuit design and the experiment begins. Voltage values are set by the student in order to achieve a temperature increase. Then, the student observes the resistance values to decrease and the temperature values to increase. If he manipulates the settings so that temperature increases at a constant slow rate, then, resistance variation recording will be successful.

The software using the appropriate formalisms (that are shown in a textbox) will convert the measured resistance of the sample into conductivity (σ) using its dimensions and measured in S/m.

During the experimental procedure a plot like the one of Figure 4 gradually forms and at the end of the experiment its slope is calculated and presented on it. Using this slope the software calculates the energy gap E_g through the equation:

$$\text{slope} = -(1/1000) \cdot (E_g / 2k)$$

where, k is Boltzmann's constant equal to

$$k = 8.6 \cdot 10^{-5}\, eV \cdot K^{-1}$$ In this case Eg = 0.65 eV.
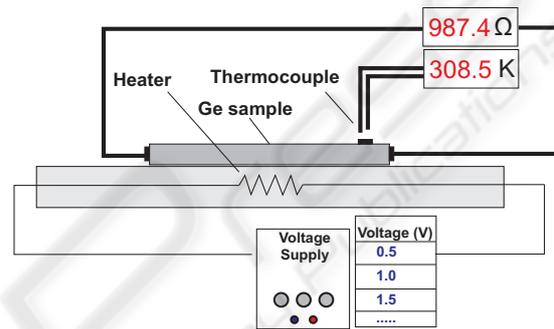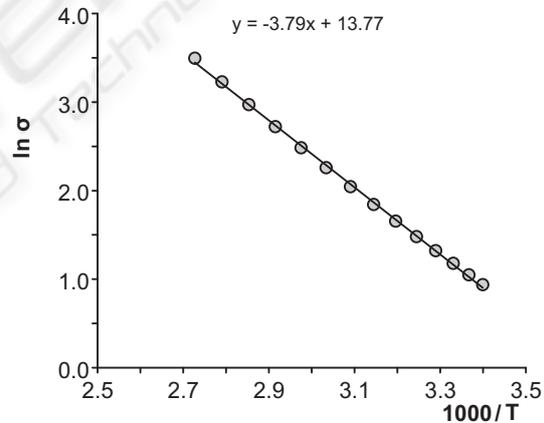

Figure 3: Typical circuit with a Ge crystal.

Figure 4: Plot of lnσ:1000/T for the calculation of the energy gap of Ge crystals.

5 RESULTS

The impact of this method of conducting laboratory experiment on the students' performance is discussed here.

The software was provided to a number of students that agreed to use it as a guide in order to get prepared for the laboratory module (open virtual laboratory). Preliminary multiple- choice question

tests on the module topic were given to the students just before conducting the laboratory experiment. Two sets of students participated in the tests; a) 31 students that had no access to the software and had to prepare for the laboratory in the traditional way and b) 34 students that had acquired the software before the experiment and prepared the laboratory using it.

Figure 5 shows the results of these two sets of students. The grey bars represent the preliminary test results achieved by the students that had no access to the software. The white bars represent the performance of the students after using the software. It becomes evident that the use of the software affects the results since the number of the students that successfully complete the tests (grade > 5.0) is larger than that of the ones who never used the software.
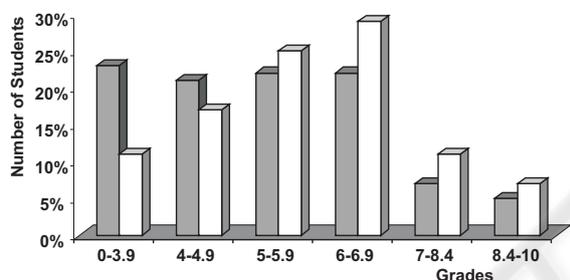
Figure 5: The impact of software on students preliminary tests.

The laboratory experiment was conducted using two methodologies. A set of 40 students selected to use traditional hardware instruments with manual controls and a second set of 37 students used the software to conduct the measurements (close virtual laboratory). After the experimental procedure each student handed in an assignment. The grades achieved by the students of the two sets after completing the assignments are presented in Figure 6. Grey bars present the performance of the students that conducted the laboratory experiment in the traditional way. White bars present the grades of the students that used the software to conduct the experiment.

It becomes obvious that the students who conducted the experiment using the software achieved higher scores on the assignments. Another important observation is that the students that achieve high scores (>8.4) are not significantly affected in any of the evaluation processes, preliminary test or final assignment.

This observation manifests that the main target this software achieves is to stimulate the interest of students and make them study the experiment concepts and the underlying theory before taking the laboratory. The most impressive result is that in both evaluations (i.e. preliminary test and assignment) students that could not achieve the pass level (>5), after using the software, seemed to understand and digest enough the underlying theory of the experiment.
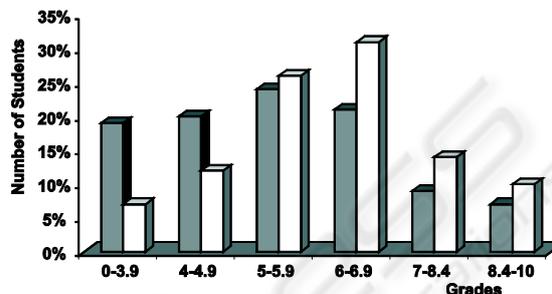
Figure 6: The impact of software on students assignments.

6 CONCLUSIONS

A virtual laboratory tool was built and evaluated using both open and close virtual laboratory methodologies. Motivation of this work was the lack of preparation before the laboratory modules from the students' side. It is concluded that a software tool provided to the students before taking the laboratory can increase their performance since it stimulates them to prepare better for the upcoming laboratory module. It is also observed that this tool mainly serves lower score students since according to the evaluation tests they are mainly helped to achieve a pass score.

Finally, it can be stressed that such tools may be used either before the experimental course as additional learning tools or they may replace some laboratory experiments increasing in this way the interest of students and consequently their performance. Moreover, new experiments and extensions of the existing ones can be implemented in order to keep the topic updated and beneficial for the students.

REFERENCES

Ali, N.S., Hodson-Carlton, K., Ryan, M., 2004. Students' perceptions of online learning: Implications for teaching, *Nurse Educator*, 29, pp. 111-115.

Cheng, Y.K. Cheng, K.W.E. Kwok, K.F, Cheung, T.K., 2004. New medium teaching method for power

electronics, *First International Conference on Power Electronics Systems and Applications*, pp. 278- 283, 9-11 Nov. 2004.

DeBord, K.A., Aruguete, M.S., Muhlig, J. 2004. Are computer-assisted teaching methods effective? *Teaching of Psychology*, 31, pp. 65-68.

Dede, C., 2000. *Emerging technologies and distributed learning in higher education.* D. Hanna, ed., Higher Education in an Era of Digital Competition: Choices and Challenges, Atwood, New York, pp. 71-92.

Epstein, J., Klinkenberg, W.D., Wiley, D., McKinley, L., 2001. Insuring sample equivalence across Internet and paper-and-pencil assessments, *Computers in Human Behavior*, 17, pp. 339-346.

Kumar, A.N., 2003. The effects of closed labs in computer science I: An assessment. *J. Comput. Sci.Colleges* 18, 5, pp. 40-48.

Fox, R., 2002. Online technologies changing university practices, A. Herrmann & M. M. Kulski, Eds. *Flexible Futures in Tertiary Teaching,* Curtin University of Technology, Perth, WA., pp.235-41.

Hart, D.W., 1993. Circuit simulation as an aid in teaching the principles of power electronics, *IEEE Transactions on Education*, vol. 36, no. 1, February 1993, pp. 10-16.

Hudgins, J.L. Monti, A. Dougal, R., 2002. Control system laboratory: a power electronics teaching experience" , *2002 IEEE Workshop on Computers in Power Electronics*, 3-4 June 2002, pp. 112- 116.

Soh, L-K, Samal, A., Nugent, G., 2005. A framework for CS1 closed laboratories, *Journal on Educational Resources in Computing (JERIC)*, Volume 5 , Issue 4.

Stavrakas, I., Kontogiannis, T., Panaousis, M, Kaitsa, M., Daradimos, I., Georgiou, T., Blathras G., Triantis, D., 2005. Beowulf Clusters for Parallel Programming Courses, *IEEE – EUROCON*, pp. 791-794.

Stergiopoulos, C., Tsiakas, P., Kaitsa, M., Triantis, D., 2006. Evaluating electronic examination methods of students of electronics. Effectiveness and comparison to the paper-and-pencil method, *IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing (SUTC 2006)*, June 5-7, Taichung, Taiwan.

Triantis, D., Stavrakas, I., Tsiakas, P., Stergiopoulos, C., Ninos, D., 2004. A pilot application of electronic examination applied to students of electronic engineering: Preliminary results, *Advances in Engineering Education*, vol. 1, Issue 1, pp. 26-30.

Triantis, D., Stergiopoulos, Ch., Tsiakas, P., 2009. Comparison of Oral Examination and Examination Methods Based on Multiple-Choice Questions Using Personal Computers, *Proceedings of the International Conference on Computer Supported Education (CSEDU 2009), 23-25,* March, Lisboa, Portugal, pp. 13-18.

Tsiakas, P., Stergiopoulos, C., Nafpaktitis, D., Triantis, D., Stavrakas, I., 2007. Computer as a tool in teaching, examining and assessing electronic engineering students, *IEEE – EUROCON – Computer as a tool,* Poland, Warsaw, September 9-12, pp. 2490-2497

Tsiakas, P., Stergiopoulos, C., Kaitsa, M., Triantis, D., 2005. New technologies applied in the educational process in the TEI of Athens. The case of "e-education" platform and electronic examination of students. Results. *WSEAS Transactions on Advances in Engineering Education,* Vol. 2, pp. 192-196.

Ubell, R., 2000. Engineers turn to e-learning, *IEEE Spectrum*, Vol. 37, pp. 59-63, no. 10, October.

Ventouras, E., Triantis, D., Tsiakas, P., Stergiopoulos. Ch., 2009. Comparison of examination methods based on multiple-choice questions and constructed-response questions using personal computers. *Computers & Education,* vol. 54, pp. 455-451 (2010).