MULTIMEDIA PROGRAMMES TO TEACH PRACTICAL AND INDUSTRIAL EXPERIENCE DURING THE EDUCATION

Tom SELS[1], Pieter VERMEYEN[1], Michel MACHIELS[2], Daniel VAN DOMMELEN[1], Ronnie BELMANS[1]
[1] Katholieke Universiteit Leuven-Belgium [2] Union Internationale pour les applications de l'Électricité-France
tom.sels@esat.kuleuven.ac.be michel.machiels@electrabel.com

Summary: *In general, engineers have to tackle technical and practical problems. Therefore, it is important that engineering students gain practical experience in parallel with theoretical knowledge. This need is mainly fulfilled in laboratory sessions. One of the major drawbacks concerning this option is the limited physical capacity of laboratories, every student can only spend a few hours for doing an experiment without the possibility to repeat it later on. Therefore, an educational computer program, "Maxwell", is developed at the department of Electrical Engineering of the Katholieke Universiteit Leuven, in collaboration with three Polytechnical Engineering Institutes. Maxwell is an interactive environment covering a number of engineering courses, which permits the students to simulate laboratory experiments on their computer before attending the laboratory sessions to prepare them or afterwards to repeat. The students who used Maxwell are very pleased with it and say that is a useful and valuable addition to the theoretical courses and the laboratory sessions.*

INTRODUCTION

A large number of electrical and electromechanical engineers start their professional career in technical functions. They are supposed to perform a diversification of tasks consisting of selecting, implementing and using electrical systems in industrial environments. Because companies appreciate young engineers having a certain amount of technical and practical experience, there is a need for educational programs offering experience oriented activities combined with the necessary theoretical background. By offering students the possibility to gain practical experience, their technical and practical autonomy are increased. Until now, this is always done by organizing laboratory sessions together with computer based simulation exercises in support of the theoretically taught technical courses. Doing so has the advantage of using a well established route. However, few drawbacks became more and more visible over the last decade.

It is important to integrate several technical topics, as treated in the courses, in the laboratory sessions. Since modern electrical energy applications such as drives, efficient lighting systems, electro-heat applications and distributed energy systems are operated using several aspects of software, micro -and power-electronics and electrical machines, laboratory sessions have to be organized to simulate and teach the dynamic behaviour of the combined system to students. Organizing such kind of laboratories requires expensive equipment and a large amount of space for each set-up. Because of these limitations and for reasons of safety, only small groups of students can participate in one session. Besides practical limitations, there are also limitations in logistics since teaching staff is only able to spend a certain amount of time for supervising laboratory sessions. Therefore, students are restricted to a limited amount of time for executing each laboratory experiment. On the other hand, many students appreciate hands-on and they also wish to repeat certain experiments and explore the entire range of operating conditions and limits of the equipment in order to achieve complete understanding. Considering the limitations mentioned above, this is virtually impossible. An ideal solution to this problem can be offered by a powerful software environment, enabling users to simulate laboratory experiments in an interactive way an on their own level and speed [1]. Such an environment might also contain sections providing additional information and elaborating theoretical and practical aspects. Using such kind of program, students can repeat laboratory experiments and execute additional experiments, impossible in the laboratory. The program can also be used to prepare the laboratory sessions and to repeat theoretical aspects taught during the ex-cathedra courses.

A similar approach is often used in industry. When time, money or space are limited, certain processes or situations are simulated using computer programs instead of building prototypes or performing real tests. Engineers can investigate abnormal operating conditions and explore the limits using computer simulations. If all these requirements have to be fulfilled in reality, the results are often dramatically such as a break down of the system or even spending too much money in prototyping. By the approach as proposed here, engineers improve their experience and self-confidence. Using a software environment in educating students has also the advantage that related topics from different courses can easily be integrated into larger, complex systems, similar to real industrial applications. Such a computer program is seen as an excellent instrument for training all-round engineers in future.

Therefore, in 1997, the K.U.Leuven-Belgium and three polytechnics embarked in developing an educational computer program based on an interactive participation of the users, in first instance their students:

- Katholieke Universiteit Leuven, dept. Electrical Engineering,
- Karel de Grote-Hogeschool Antwerp,
- Provinciale Industriële Hogeschool Kortrijk,
- Katholieke Hogeschool Kempen Geel.

The results of the project, known as "Computer supported

laboratory for production oriented electrical systems," is an interactive tool carrying the name of "Maxwell", [1],[2], [3].

MAXWELL : INTERACTIVE TRAINING

Goals of an Interactive Training Module

Developing an interactive training program like Maxwell does not only involve technical content, but has also psychological and pedagogical demands:

1. Combine all subjects and topics from the different courses into one software environment, using one programming language: in this way the programming effort is minimal and future extensions are easily.
2. The software has to be seen as a tool for individual learning. It will allow students to study certain subjects at their own level and speed in a familiar environment, at home.
3. Complex technical systems as well as their basic parts are treated. By providing many interactive sections, it increases the students' practical experience.
4. An interactive program is a reflection of the principle that modern engineers use to develop and execute new projects. Engineers are not anymore supposed to solve sub-problems, they have to provide global solutions and take care of all aspects of a problem. Besides this, industrial processes and projects are nowadays developed using software tools. Important situations and all interacting elements are analyzed in advance with as less prototyping as possible.

The program is developed in such a way that it is usable for engineering students in the Bachelor and Master program, specializing in electrical, electromechanical, mechanical or chemical engineering at university level. Besides this, Maxwell needs also be usable during the training of undergraduates and graduates in companies or at polytechnics. This global approach serves the introduction of the Bachelor Master-structure at Belgian universities and polytechnics.

Additional Requirements

Choice of the programming environment. An important characteristic of a programming environment is its simplicity. This attribute has to be interpreted in two ways. The developing environment used to write the source code of Maxwell, needs to be simple and transparent in two ways. It allows other programmers to extend the program without much effort. On the other hand, students should be able to use the program without necessity of buying additional and sometimes expensive hardware or software. Problems concerning license agreements have to be solved upfront. Since Maxwell is supposed to be a non-commercial program, an educational version of Authorware was purchased, making free distribution of the developed software among students possible. Authorware, distributed by Macromedia, is an icon-based program with several advantages over other similar programs [4]:

- It allows efficient programming and quick development of multimedia based applications after only a short training period.
- It can also be used to assemble multimedia programs, executable in a Microsoft Windows environment.
- The distribution of the programs can easily be done via the Internet.
- There is its ability to combine electronic documents and pictures of different types into larger units, without having to alter document types. Therefore, it is easy to replace documents without interfering in the source code.

Distribution of Maxwell. With the distribution of software, intellectual property rights have to be taken care of. After inquiry of the developers of Authorware and the authorities, the decision made to issue copies of Maxwell on CD-ROM, via the Internet or via intranet of the participating institutions is made. For each distribution channel, it remains possible to install Maxwell on a local hard disk or to use it directly, without installation, from the web.

Operating system and additional software requirements. Maxwell is designed for execution on a multimedia PC with a Microsoft Windows operating system. Microsoft Windows is chosen because many students use it at home and because it is the de facto standard when buying a new PC. Students also have access to PC's at their school. Additional software requirements to run multimedia applets and movies, such as Windows Media Player and Real Player, are downloadable for free or already included in the operating system. For processing simulation results, a standard office word processing and spreadsheet program can be used, but not necessarily required.

STRUCTURE OF MAXWELL

Until now, Maxwell covers five topics of electrical engineering: energy, sensors, controllers, electronics and composed systems. A sixth section on physical principles can be seen as an introduction [2]. A screen dump of Maxwell's openings screen is displayed in Figure 1. The section of "Energy" summarizes topics as measurement devices, transformers, DC machines, induction machines, servo drives and electroheating. Laboratory sessions and theoretical aspects of temperature, pressure, flow, level and displacement sensors are collected in the "Sensor" section. PID and fuzzy controllers together with artificial neural networks are discussed in "Controllers." Section "Electronics" focuses on micro-controllers while in "composed systems," the control

aspects of servo drives are discussed as an example incorporating many aspects of the other parts.

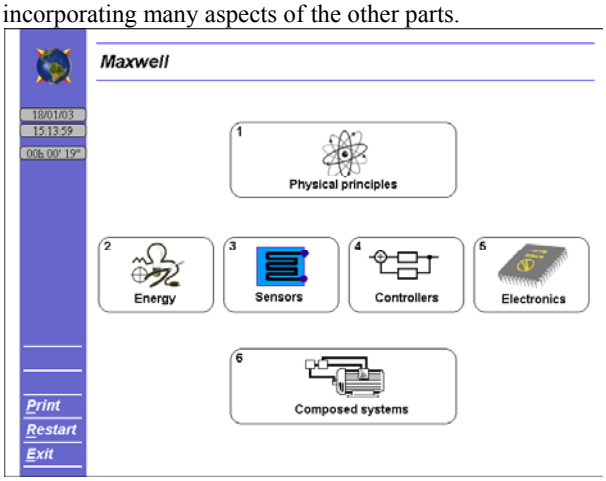

Figure 1 : Opening screen of Maxwell

All topics are structured in the same way and the same layout is used throughout the program: When starting the program, the six themes appear for being selected by the user by a simple mouse click (e.g. energy) after which a list of different topics belonging to that theme appears. Within every topic, the same structure is used for handling the different aspects:

1. **Principles:** The principles necessary for understanding the subject are explained. Often animations are used to clarify complicated concepts.
2. **Formulae:** The mathematical formulae describing the subject are given. Animations and interactive buttons are used to explain theory.
3. **Simulations:** Laboratory experiments are simulated with a high degree of realism.
4. **Technology:** The construction and technical aspects of machines and devices are explained in more detail.
5. **Expert:** Technical or other related materials are explained in detail. These extras are not treated in any of the courses. It provides interested students with additional information.
6. **Questions:** The user's knowledge is tested by means of multiple-choice questions spread over different levels.

The simulations are designed to resemble real experiments. In a similar way, the user has to select the test object and the necessary measurement devices before starting the experiment. All experiments can also be executed using different combinations of equipment as Volt, Amp or Watt-meters. An example of a load test of a single phase transformer is displayed in Figure 2. In some experiments also the necessary connections to build the test set-up can be drawn. Another interactive aspect included in the simulation, is the calculation and adjustment of some of parameters by the user. The interactivity and communication with the user is built in using several techniques (Figure 2):

- Slide bars and buttons (slide switch, dials, etc) to increase the value of parameters,
- Push buttons to increase the value of a parameter by one unit,
- Fields controlled by the user to fill in a numeric value,
- Automatically varying of parameters within an interval.

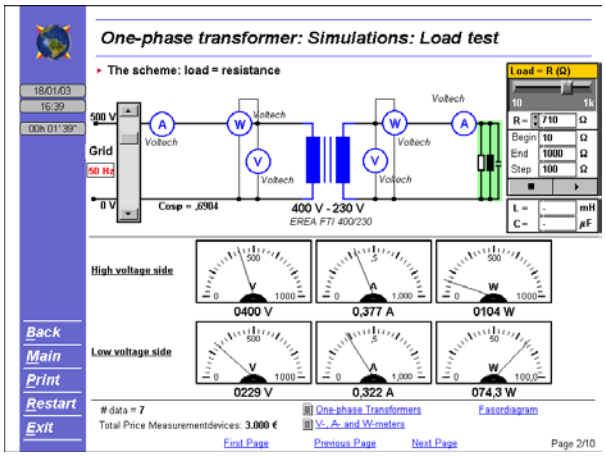

Figure 2 : Simulation of a load test of a single phase transformer

The simulation results in a set of numbers listed in a table or presented in a graph. Those values are also saved in an output-file and can easily be manipulated using standard spreadsheet programs for analyzing results, drawing conclusions and checking against theory.

As noted from Figure 2, several 'hot' buttons are present to navigate through the program. The main buttons are always present at the left-hand site, while there are several temporary navigation buttons present at the bottom site to jump between different screens of a typical topic. Finally, a lot of interactive buttons are also available within the different screens such as when building up a figure with accompanying text, to start a simulation or a movie or to reveal additional information.

DISTRIBUTION AND COMMENTS OF MAXWELL

The Target Group

The target groups are mainly Bachelor or Master students in engineering and undergraduates from polytechnics. With Maxwell, they have the opportunity to study in an interactive way and to prepare or repeat laboratory experiments and the theory on a different level. Clearly, there are considerable differences in technical knowledge and experience between those groups, a different type of basic education mainly causing the differences. However, thanks to Maxwell it is possible to compensate and by-pass this different basic knowledge. After studying with Maxwell, the less experienced students are more self-confident when executing experiments in the laboratory or passing a theoretical examination.

Concerning electrical engineering students, Maxwell is mainly aimed at third-year students. In future they will

receive their Bachelor degree at a university or polytechnics at the end of this year. However, the polytechnic students have more technical experience than the university ones, who have more experience in mathematics. Both of them can use Maxwell to fulfill their own needs. In general, Maxwell covers students of different engineering departments such as electrical, mechanical, power, chemical, computer science and material science. All students enroll in one or more electrotechnical courses.

Apart from being a tool just for students, the program has also created opportunities for master students being in their final year: the development of the program gave rise to a number of master thesis projects. These projects consisted of evaluating and making changes to the program, developing certain sections or creating three-dimensional animations on construction and functioning of certain electrical machines.

Feedback from the Students

To have an idea of the students' opinion on Maxwell, a number of inquiries have been performed over the years. The first poll was carried out during the academic year 1998-1999. The students of the participating institutions received a questionnaire, as part of a master thesis project. Maxwell was still in a premature stage, so remarks of students could immediately be translated into further adaptations. This inquiry is repeated at the Katholieke Universiteit Leuven in the years 2000-2001 and 2001-2002 to follow up the integration of Maxwell into the student's curriculum.

The students are asked to evaluate Maxwell according to two groups of criteria with easy questions, 12 in total: the first group concerns mainly questions related to the usability when preparing laboratory experiments and repeating theory. The second group is more related to practical topics allowing some conclusions over the user-friendly level of Maxwell. Every statement is easily evaluated using always the same procedure.

Besides the closed nature of every question, they are also extended with possibility to give free remarks for proposals of changes to the program. The results of some random polls are briefly discussed in the next paragraphs.

During the first premature stage of Maxwell, the first student version 1998-1999, the remarks of the students to the open part of the questions can be summarized as follows:

- A lot of remarks were about the distribution and installation of the program. Downloading via the Internet took a long time and sometimes failed. Students proposed distributing Maxwell on CD-ROM and installing it on all PC's of the department. The installation procedure had also some drawbacks. For some students, there was a problem of having a powerful and at the time expensive computer required to run the program in a smooth way.
- A second group of remarks concerned navigating through the program. The students thought that an index and a search function would be useful. They also suggested the tree structure to be modified and changed to a more transparent tree.
- In general the students were very satisfied with the program. Their final conclusion is that Maxwell can be a valuable addition to the lessons, the theoretical exercises and the laboratory sessions. Out of the three groups, the reactions of the students of the Katholieke Universiteit Leuven were the most positive.

The number of students, their institute and technical background of the first survey is summarized in TABLE 1.

TABLE 1 : Student numbers of the first survey during 1998-1999

Background	# students	Specialization Year
Katholieke Universiteit Leuven		
Electrical & Mechanical Engineering	129	3th - first year of specialization
Provinciale Industriële Hogeschool Kortrijk		
Electro-Mechanical Engineering	20	3th - first year of specialization
Electrical Engineering	15	4th - last year of specialization
Karel de Grote-Hogeschool Antwerp		
Electronics & Biochemistry	23	3th - first year of specialization

During the years 2000-2002, the remarks of the students were as far as possible integrated in new versions of Maxwell. The today's version of Maxwell is positively evaluated by the students of last academic year, 2001-2002. The survey group was, as before, third year students in Electrical and Mechanical Engineering of the University of Leuven. The population of the survey is 108 students. The results of some representative questions are discussed below.

To the question whether using of Maxwell to prepare the laboratories reduces the risk and danger and improves the safety level of the laboratories, the reaction of the students is clear (Figure 3). The students are not convinced that Maxwell enhances the safety level. Figure 3 yields that only 37 % is satisfied against 63 % with no opinion or not fully convinced. This results confirms the statement that it is still necessary to get practical experience in the field, and that there are still some attitudes and skills that cannot be learned only via a computer program.

To get an idea of the feasibility of the main aims of Maxwell, two questions regarding theoretical and practical content of Maxwell are highlighted:

- Using Maxwell to prepare the laboratory sessions enhances understanding and self-confidence during the labs (Figure 4.)
- Maxwell supports repeating theory after attending labs (Figure 5.)

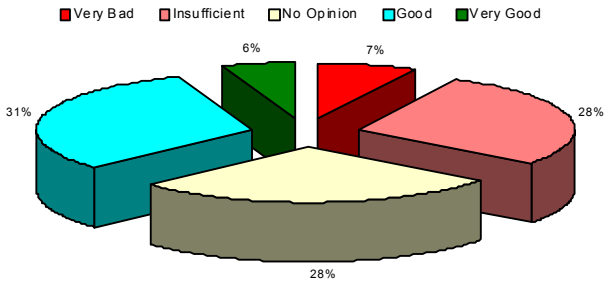

Figure 3 : Question: Preparing laboratory sessions using Maxwell reduces the danger and risks and improves safety during labs

Looking at both figures, it appears that according to the students those aims are achieved. Figure 4 yields that at least 67 % of the students agree that Maxwell enhances understanding and self-confidence during the laboratory sessions. The supervisors of the laboratories also confirm this. They see that more and more students use printouts of Maxwell during the lab sessions and that they use it as a kind of hot line for solving problems during discussions and calculating parameters. Maxwell supports also the students, after they attended the labs, when studying theory for their exam. From Figure 5 it can be noted that 69 % of the students confirm this statement. During the exam, being an open-book, the students use also printouts for explaining theory or as a mnemonic.

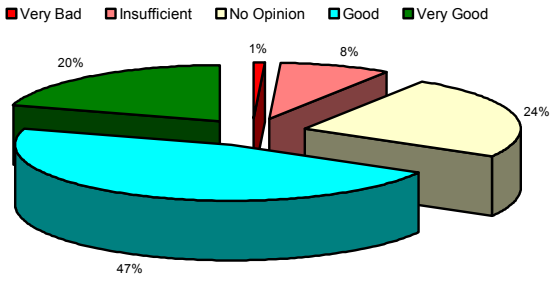

Figure 4 : Question: Using Maxwell to prepare the laboratory sessions enhances the understanding and self-confidence during the labs

The other questions of the survey focus mainly on software and hardware environment. They are more dependent on the available computer infrastructure and student's computer skills. Therefore, they are more a feedback for the programmer.

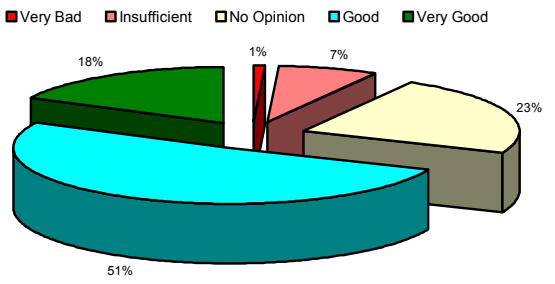

Figure 5 : Question: Maxwell supports repeating theory after attending the labs

Use of Maxwell at the Participating Institutes

Since the development in 1998 and further evolution towards today's version, Maxwell is used at the four participating institutes in a different way and for different types of students:

- At the **Katholieke Universiteit Leuven** the program is used since 1998 as a learning tool, in support of courses, lectures and laboratory sessions such as “Electricity and Electrical Energy” and being attended by third-year electrical and electromechanical engineering students.
- At the **Provinciale Industriële Hogeschool Kortrijk** the software is not anymore integrated in the courses at this time. However, the program will be used in future after the conversion to the Bachelor-Master structure of higher education in Belgium.
- Since 2001 Maxwell is used at the **Centre for Post-University Education of the Katholieke Universiteit Leuven Campus Kortrijk** in training teachers for basic education (students between 16 - 18 year old).
- At the **Karel de Grote-Hogeschool of Antwerp** the program was used in support of laboratory sessions of the course “Electrical Machines”. Since 2000 the lecture teaching this course is changed with the consequence that the content of the laboratory sessions was altered and the Maxwell is not used anymore.

CONCLUSIONS

An educational computer program is developed at the department of Electrical Engineering of the Katholieke Universiteit Leuven in close collaboration with three Belgian polytechnics. The program called Maxwell is an interactive environment covering several topics of electrical engineering and can be used by undergraduate and master students to prepare themselves for practical laboratory sessions and when repeating and studying theory for the final examination.

The program is now in use for more than four years at the University of Leuven to assist in one of the technical courses "Electricity and Electrical Energy" taught in the first technical year (3th year). Every year, a survey to evaluate Maxwell is held among the students after which the useful remarks are integrated in a new version of Maxwell.

In general the students are pleased with Maxwell and they find it a valuable addition to the theoretical courses and laboratory sessions. 69 % of the students confirms that Maxwell supports them during studying theory for their final exam after they attended the laboratories. An almost equal number, 67 %, agree that Maxwell enhances understanding and self-confidence during the laboratory sessions, as confirmed by the supervisors of the practical sessions. However, the majority of students, 63 %, is not fully

convinced that using Maxwell to prepare the practical sessions enhances the level of safety and reduces the risks and dangers of the laboratories. This is not a real negative reaction for Maxwell, as it confirms the generally recognized feeling that it is still necessary to get practical experience in the field, and that there are still some attitudes and skills that cannot be learned by only a computer program.

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Authors Address
Tom Sels
Katholieke Universiteit Leuven
Dept. Electrical Engineering (ESAT), Div. ELECTA
Kasteelpark Arenberg 10
B-3001 Leuven (Heverlee) - Belgium